Stationary Engineering

Fuels, Fuel Handling

and Fuel Burning Equipment

A Guide to Advanced Examinations

by

Stanley Douglas Guiling

Fuels
Fuel Handling and
Fuel Burning Equipment

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Chapter 1 Fuel Overview

The principal fuels for use in a boiler to create steam are coal, fuel oil from a refinery; natural gas, waste gas from processes like coke oven gas and blast furnace gas, and solid waste from wood or garbage (also known as refuse derived fuel or RDF). The main consideration is the overall cost of the fuel to create the steam.

Beyond the cost of the fuel is the cost of manpower and specialized equipment to handle the fuel, equipment to control the pollution created, and the cost to dispose of the waste products, if any.

The cost of the fuel over the 50 to 60 year lifespan of the plant will be many times the cost to build the plant so that flexibility in the type of fuel burned is best designed in at the beginning. The furnace should be designed large enough to burn a wide variety of coals without slagging. A pulverized coal plant with #6 fuel oil burners can switch between fuels as price and availability vary.

Fuels vary in their BTU content so it really comes down to the BTU's per pound in the fuel versus the overall cost to buy and burn the fuel per pound.

1. What criteria does the Chief Engineer need to consider when specifying a fuel for a brand new industrial boiler installation?

The main criterion is to perform a Fuel Analysis. The purpose of which is threefold:
a. Find out what fuels are available to the plant, especially what grades of coal
b. Establish the relative value of these fuels
c. Attempt to predict, or at least allow for, changes in relative value in future years.

POWER Special Report February 1974 page S-2 Fuel analysis first
Detroit Edison Steam Course page 10, Fuels and Combustion. Question #49

2. Name the BTU values for all fuels.

HEATING VALUES

Anthracite ---------- 11,500 - 13,300 BTU/lb
Semi-anthracite ---- 11,500 - 13,300 BTU/lb
Bituminous --------- 10,500 - 14,400 BTU/lb
Sub-bituminous ---- 7,800 - 11,800 BTU/lb
Lignite ---------------6,500 - 8,000 BTU/lb

GAS

Natural -------------- 800 - 1,500 BTU/cu.ft.
Manufactured ------ 450 - 600 BTU/cu.ft.

OIL

No. 1 -----------------133,000 - 138,000 BTU/gal
No. 2 -----------------135,000 - 141,000 BTU/gal
No. 4 -----------------138,000 - 144,000 BTU/gal
No. 5 -----------------145,000 - 152,000 BTU/gal
No. 6 -----------------150,000 - 155,000 BTU/gal

Kent's 12th edition page 2-16

What is the BTU per pound of a high quality bituminous coal?

14,000 BTU/ lb

What is the BTU per pound of #6 fuel oil?

18,800 BTU/ lb

What is the BTU per pound of #2 fuel oil?

19,500 BTU/ lb

What is the BTU per cubic foot of natural gas?

1,000 BTU/cu.ft.

How many cubic feet of natural gas does it take to make a pound of natural gas?

20 cu.ft.

What is the BTU per pound of natural gas?

20,000 BTU/ lb

What is the BTU per gallon of #6 fuel oil?

151,000 BTU/gal.

Detroit Edison Steam Course Fuels and Combustion. page 11 Oil measurements @ 60 degrees F

What is the BTU per gallon of #2 fuel oil?

139,000 BTU/gal.

Detroit Edison Steam Course page 11. Fuels and Combustion. Oil measurements @ 60 degrees F

Do you buy fuel oil by the pound or by the gallon?

The gallon.

Which fuel gives the most value for the dollar spent on straight fuel cost basis, #2 or #6?

#6 fuel oil

Name the proper furnace temperatures for coal and gas.

Natural Gas furnace temperatures are from 1500-2200 degrees F. Coal furnace temperatures are from 2300-2500 degrees F . http://www.weenergies.com/home/ValleyPP.pdf www.we-energies.com/home/OakCreek.pdf

Chapter 2 Coal

What is the origin of coal?

Coal was formed by the decomposition of vegetation which grew in prehistoric forests. It takes 400 years to accumulate enough vegetable matter for a one foot layer of coal.

Steam Plant Operation by Woodruff and Lammers #4 page 117

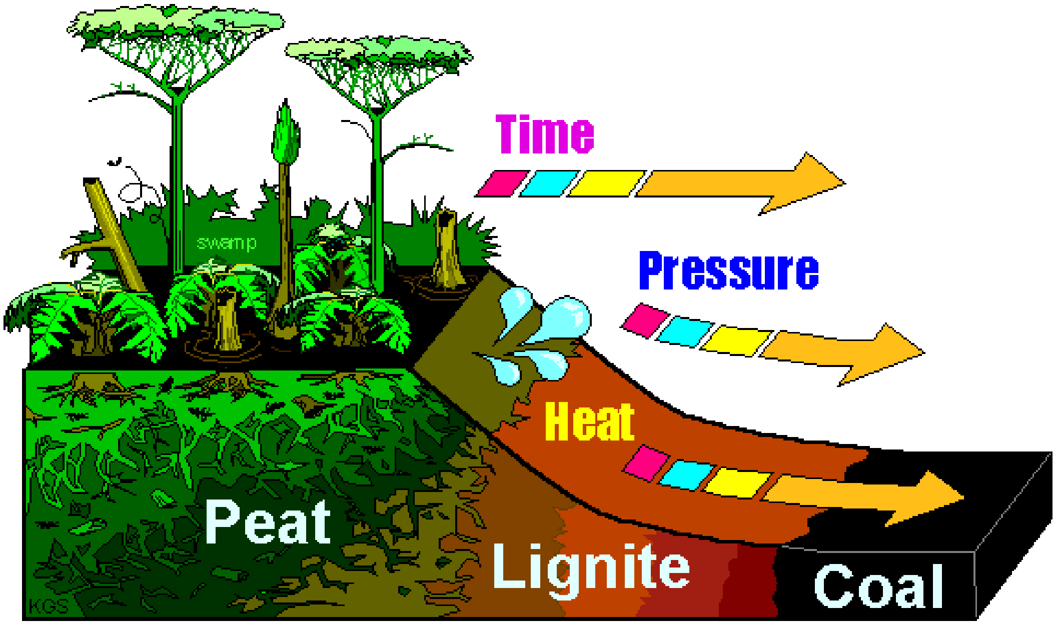
Painting of a coal forest showing a dragonfly with a 2 foot wingspan

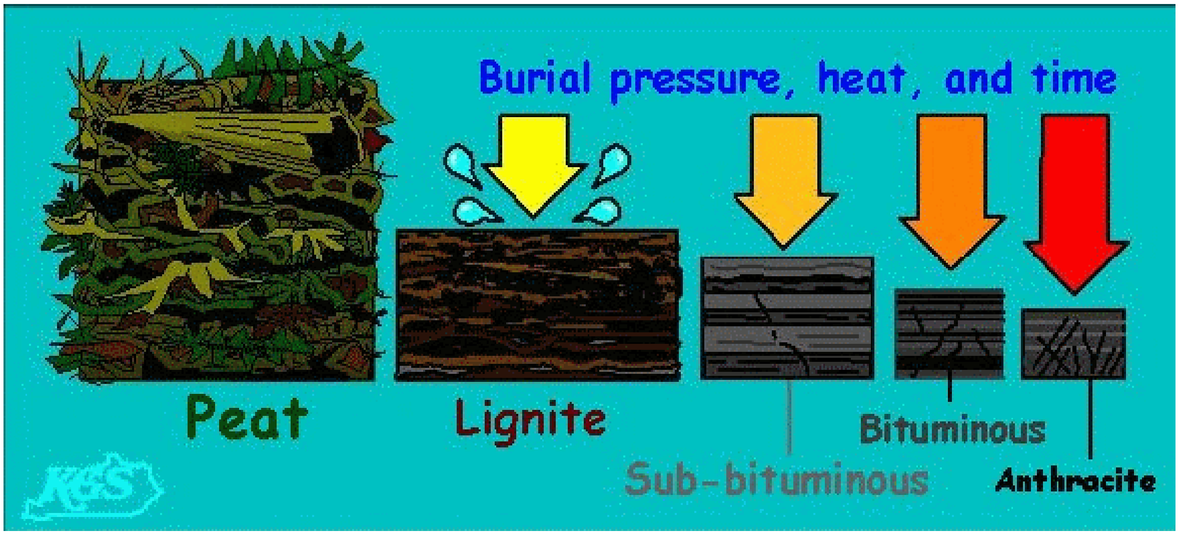
Another interpretation of the prehistoric coal forest, or else a picture of Dead Stream Swamp by Houghton Lake taken last week.

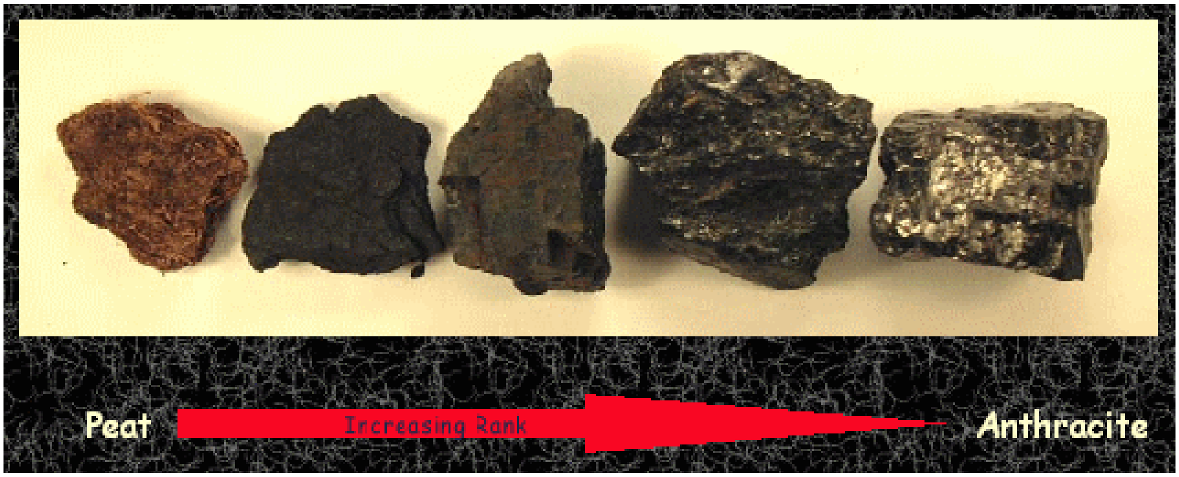
Why are there different types of coal?

The characteristics of coal depend upon the type of vegetation from which it was formed; the impurities that became mixed with the coal; the time, temperature, and pressure under which it formed.

Steam Plant Operation by Woodruff and Lammers #4 page 117







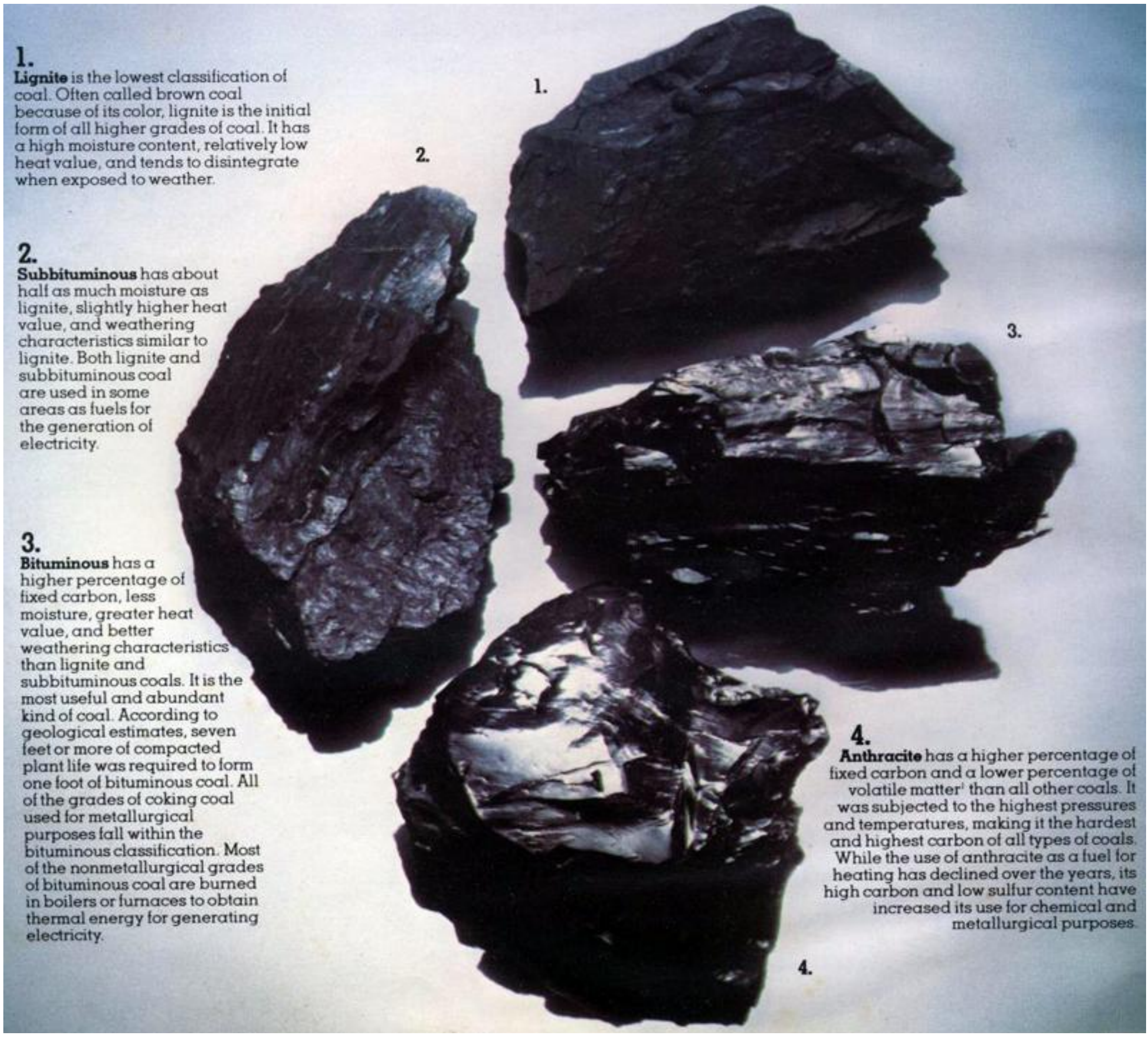
What are the different types of coal as classified by the Bureau of Mines?

In its various Bulletins the U.S. Bureau of Mines uses the following classifications for the ranks of coal

1. Lignite (lowest)
2. Sub-bituminous
3. Bituminous
4. Semi-Bituminous
5. Semi-Anthracite
6. Anthracite (highest)

The word "rank" in this connection is used to designate "those differences in coal that are due to the progressive change from lignite to anthracite, a change marked by loss of moisture, of oxygen, and of volatile matter." This change is generally accompanied by an increase of fixed carbon, of sulfur, and probably of ash. When however one coal is distinguished from another by the amount of ash or sulfur it contains, this difference is said to be one of grade. Thus, a "high grade coal" means merely one that is relatively pure, whereas a "high rank coal" means one that is high in the scale of coals. This means you could have a "high grade" Sub-bituminous that had little ash or sulfur, but a "high rank" coal would always be semi-anthracite or anthracite, regardless of impurity levels.

Steampower Plant Engineering by G.F. Gebhardt 6th edition copyright 1928 page 35



1.
Lignite is the lowest classification of coal. Often called brown coal because of its color, lignite is the initial form of all higher grades of coal. It has a high moisture content, relatively low heat value, and tends to disintegrate when exposed to weather.

2.
Subbituminous has about half as much moisture as lignite, slightly higher heat value, and weathering characteristics similar to lignite. Both lignite and subbituminous coal are used in some areas as fuels for the generation of electricity.

3.
Bituminous has a higher percentage of fixed carbon, less moisture, greater heat value, and better weathering characteristics than lignite and subbituminous coals. It is the most useful and abundant kind of coal. According to geological estimates, seven feet or more of compacted plant life was required to form one foot of bituminous coal. All of the grades of coking coal used for metallurgical purposes fall within the bituminous classification. Most of the nonmetallurgical grades of bituminous coal are burned in boilers or furnaces to obtain thermal energy for generating electricity.

4.
Anthracite has a higher percentage of fixed carbon and a lower percentage of volatile matter[1] than all other coals. It was subjected to the highest pressures and temperatures, making it the hardest and highest carbon of all types of coals. While the use of anthracite as a fuel for heating has declined over the years, its high carbon and low sulfur content have increased its use for chemical and metallurgical purposes.

What are the constituents of coal by elements and impurities?

The ultimate analysis breaks the fuel into its constituent elements, which include carbon, hydrogen, nitrogen, sulphur, oxygen, and ash. Since neither moisture nor ash adds to the heating value of the coal, analysis are calculated to exclude these constituents to give a true indication of the nature of the combustible material, thus moisture and ash free, or combustible.

I.U.O.E., Fuels, Oils, and Lubricants pages 6-1-20

What is cannel coal?

Cannel Coal

Cannel Coal

Cannel coals are clean, nonbanded, compact, blocky coals of massive structure and fine-grained texture. Usually they are dark gray to black, display a greasy luster, and have a noticeably conchial or shell-like fracture. As shown in thin sections under the microscope, these coals are composed almost entirely of attrius, (ground mass of plant debris) with very few bands of anthraxylon (coalified trunks and limbs of trees and plants). The attrius may comprise a wide variety of components, such as spore and polline exines, anthraxylon debris, oil algae, and opaque constituents.

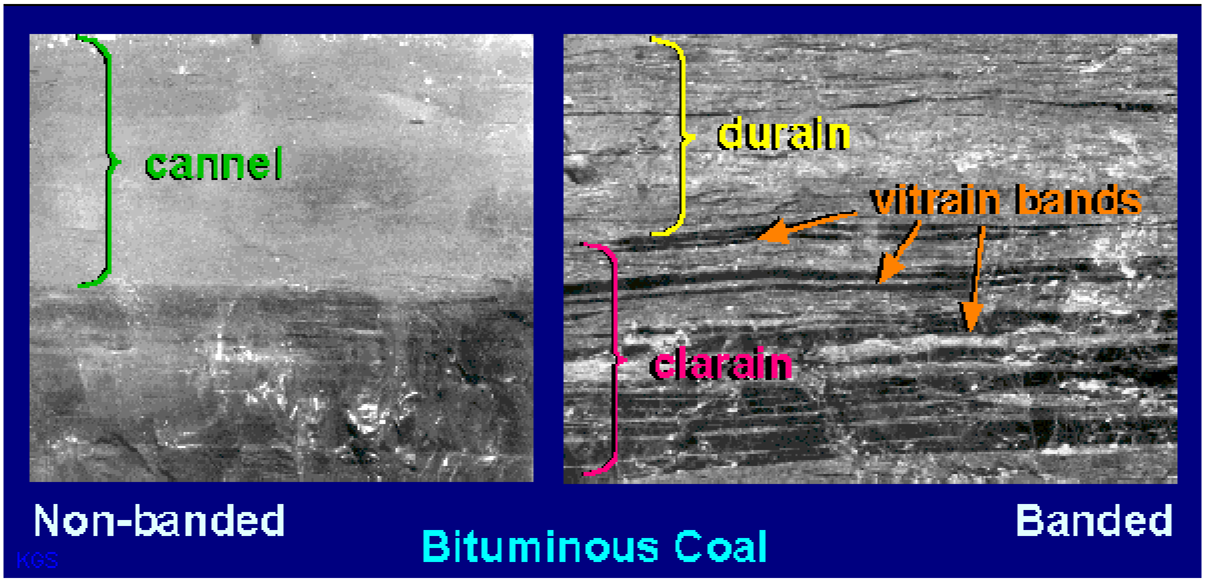
Fuels and Combustion Handbook - Johnson and Auth page 36

Cannel coal is a variety of bituminous coal found in a few small areas of several states. It has the highest hydrogen content of any coal and burns with a bright flame without fusing. It is seldom used for steam generation, but it found a ready market because of its usefulness in the enriching of illuminating gas. Cannel coal differs greatly in appearance from all other bituminous coal, being homogeneous, with a black or grayish-black color and a dull resinous luster.

Steampower Plant Engineering by Gebhardt 6th edition page 42

Cannel coal is a non-coking bituminous coal. It kindles easily and burns with a bright flame similar to a candle flame. From this circumstance it derives its name. It contains about 50% volatile matter.

This renders it valuable for gas making. Its structure is very compact. It has a dull luster. When a lump of cannel coal is broken, the fracture will appear to occur at no definite cleavage line
Croft Boilers page 219

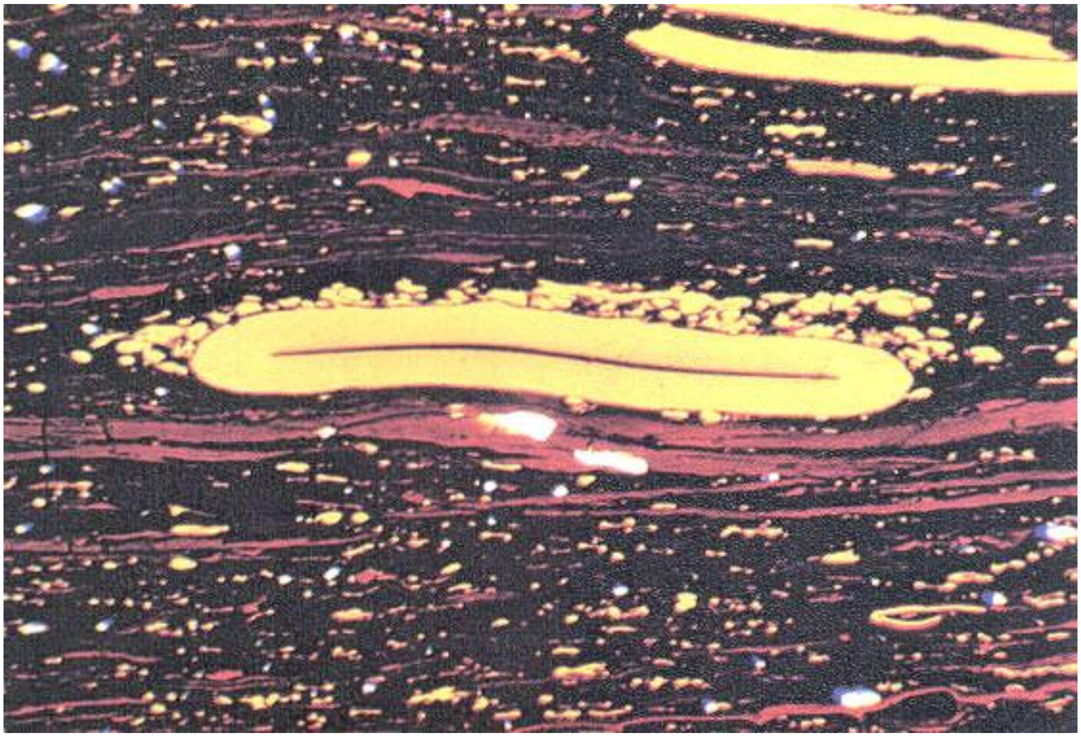


What is splint coal?

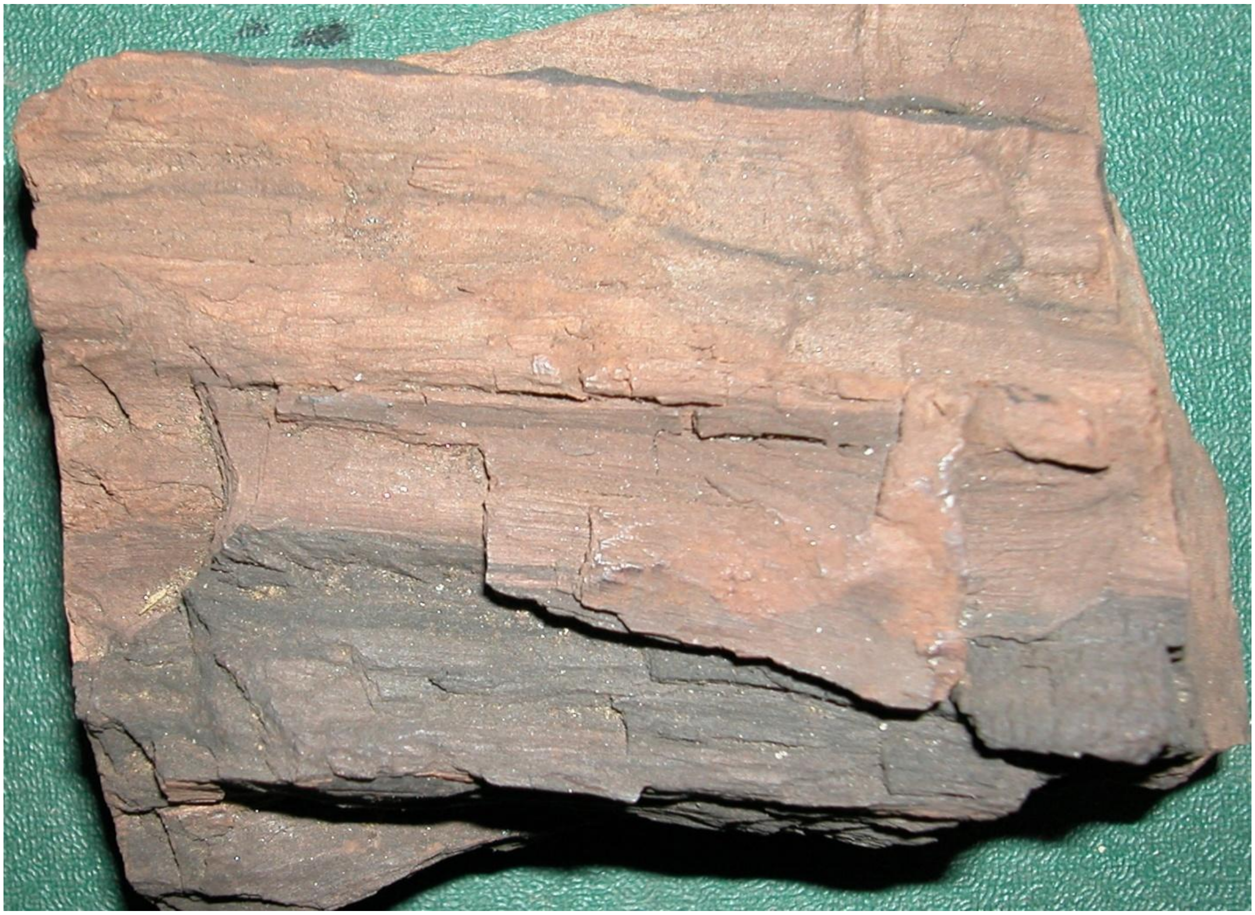
Bright coals have lots of vitrain and clarain; dull coals are rich in durain bands. Fusain generally occurs only in thin and sporadic bands. **Splint coals** are durain-rich and can be massive (nonbanded) or banded. Most vitrain-and clarain-rich banded coals break into small blocky pieces along joints, called cleats. Vitrain and clarain are brittle and break easily. "Block coals" are dull coals that break into large blocks because they have fewer vitrain and clarain bands, but have a composition higher in liptinite macerals, which are tough.

Splint coal is a free-burning bituminous, and due to the method of formation, splits along a seam like slate; although breaking on cross fracture is difficult. It is low in volatile content and slow to ignite. Because of this and its flaky structure, it is less valuable for steaming purposes than better grades of bituminous.

Power Handbook on Fuels 1934 edition page 11



Microscopic view of splint coal. The yellow object in the center was a round spore elongated by compression. The thin red bands are woody material the tiny yellow spots are spores and algae . The black is charcoal or mineral debris.



Bone Coal

What is Bone coal?

That part of the material encountered in mining which contains a large percentage of coal but not of marketable grade. The increasing cost of coal has lead to the use of this coal.

Steampower Plant Engineering by Gebhardt page 37

Impure coal that contains much clay or other fine-grained mineral matter. The term "impure coal" accompanied by adjective modifiers such as "silty," "shaly," or "sandy," is the preferred usage because the definition of bone coal does not specify the type or weight percentages of impurities. *pubs.usgs.gov/circ/c891/glossary.htm*

Coal with a high ash content; it is dull in appearance, hard, and compact.
http://www.teachmefinance.com/Scientific_Terms/Bone_coal.html

Bone Coal.—The refuse from coal mining consisting of slate and bone coal was, for many years, thrown out in great piles and considered a waste product. This refuse, however, had been used in connection with stoker-fired furnaces. It is very high in ash and low in heat value.

Mechanical stokers by Joseph G. Worker and Thomas A. Peebles 1922 page 97

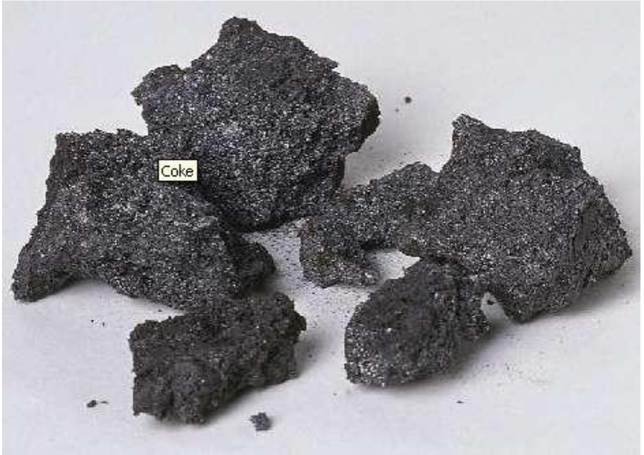
What is Coke?

Coke may be prepared from almost any fuel containing carbon, but the greater part of the commercial product comes from the distillation of bituminous caking coals. This is produced by heating the coal in a coke oven in the absence of air, drawing off the coke oven gas to be burned in the boiler, and leaving almost pure carbon behind to be used as a fuel in steel mills.

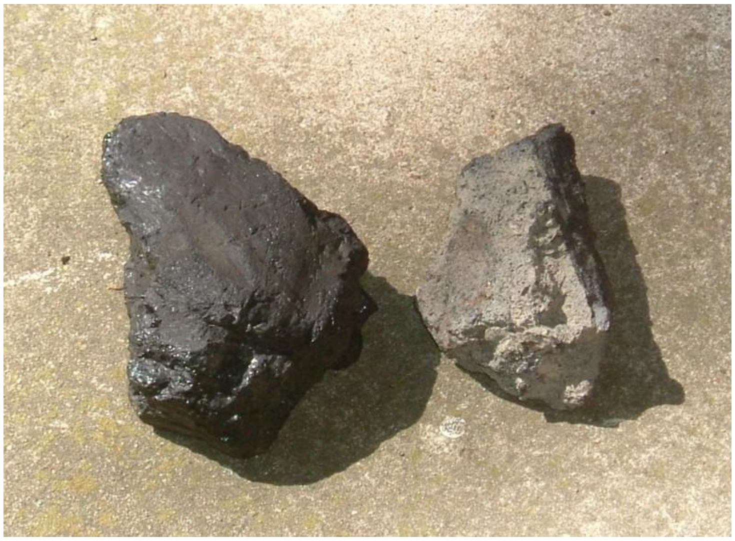
Steampower Plant Engineering - Gebhardt page 42

Coke produced rapidly and at relatively low temperatures has a loose spongy texture and is dull black in color. Coke made in the byproduct or beehive oven, where continued high temperature heating is used, is hard, dense and silver-gray in color, and has a brilliant semi-metallic luster.

Combustion Engineering page 2·34



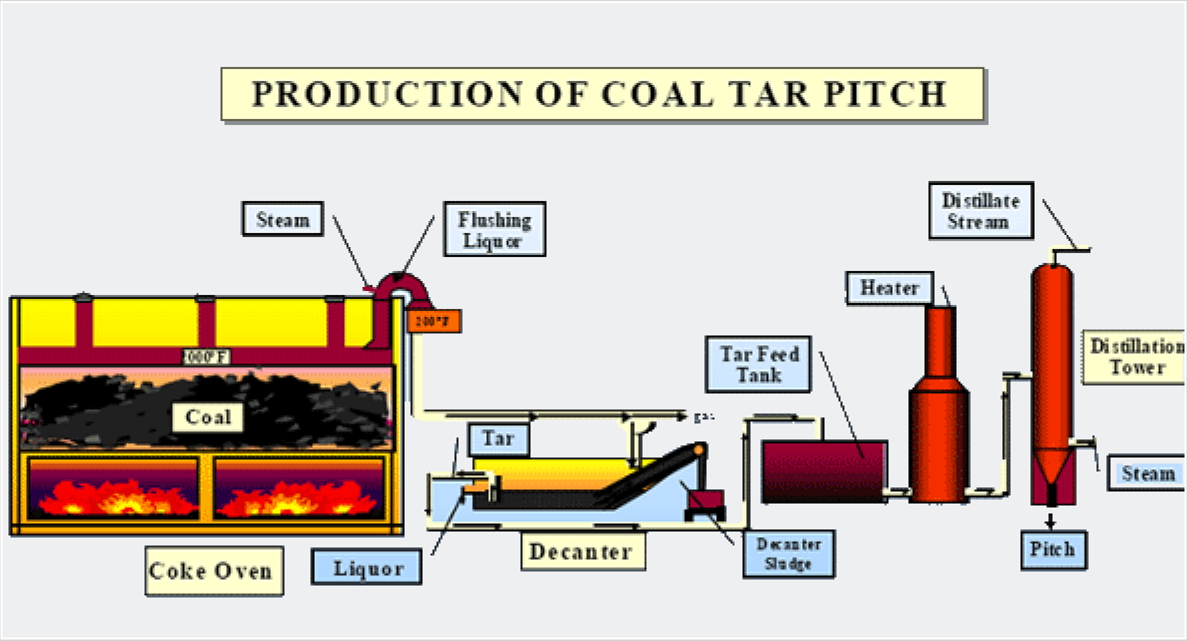
Spongy coke



Bituminous coal is on the left. Byproduct oven coke is on the right

Beehive Coke ovens

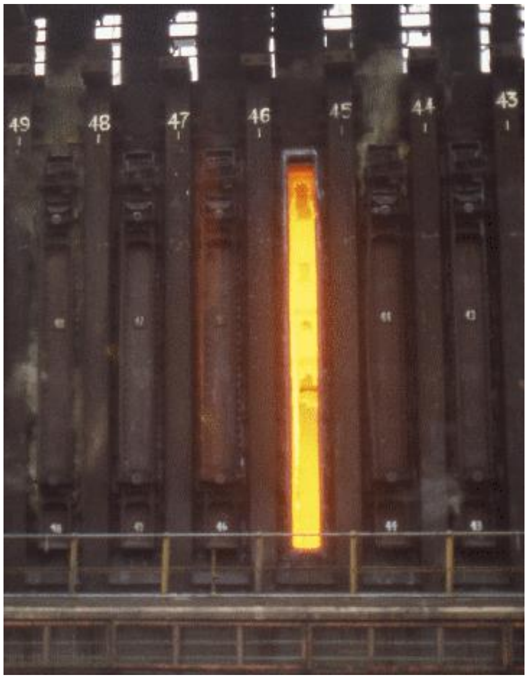
Beehive Coke ovens



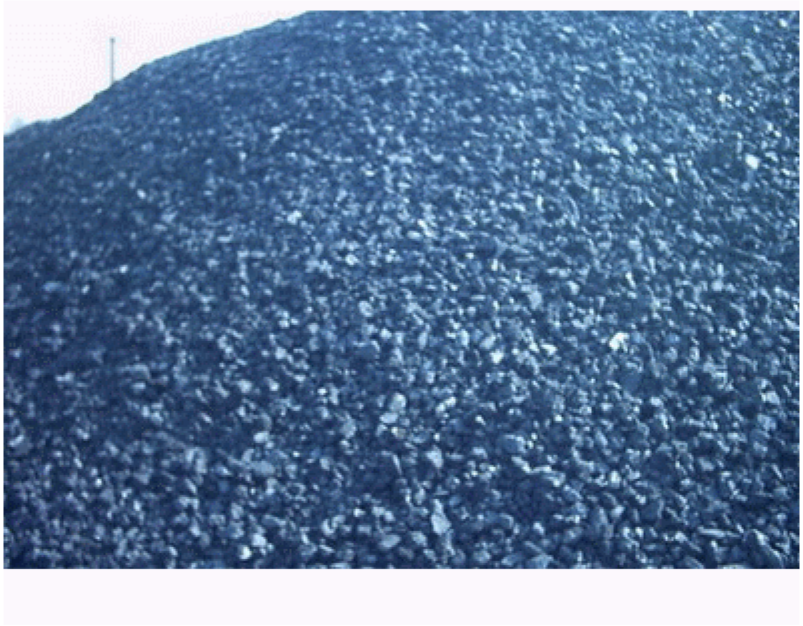
Byproduct coke oven

Coke oven battery discharging coke

Painting of Coke ovens on Zug Island by Detroit



Coke inside the coke oven

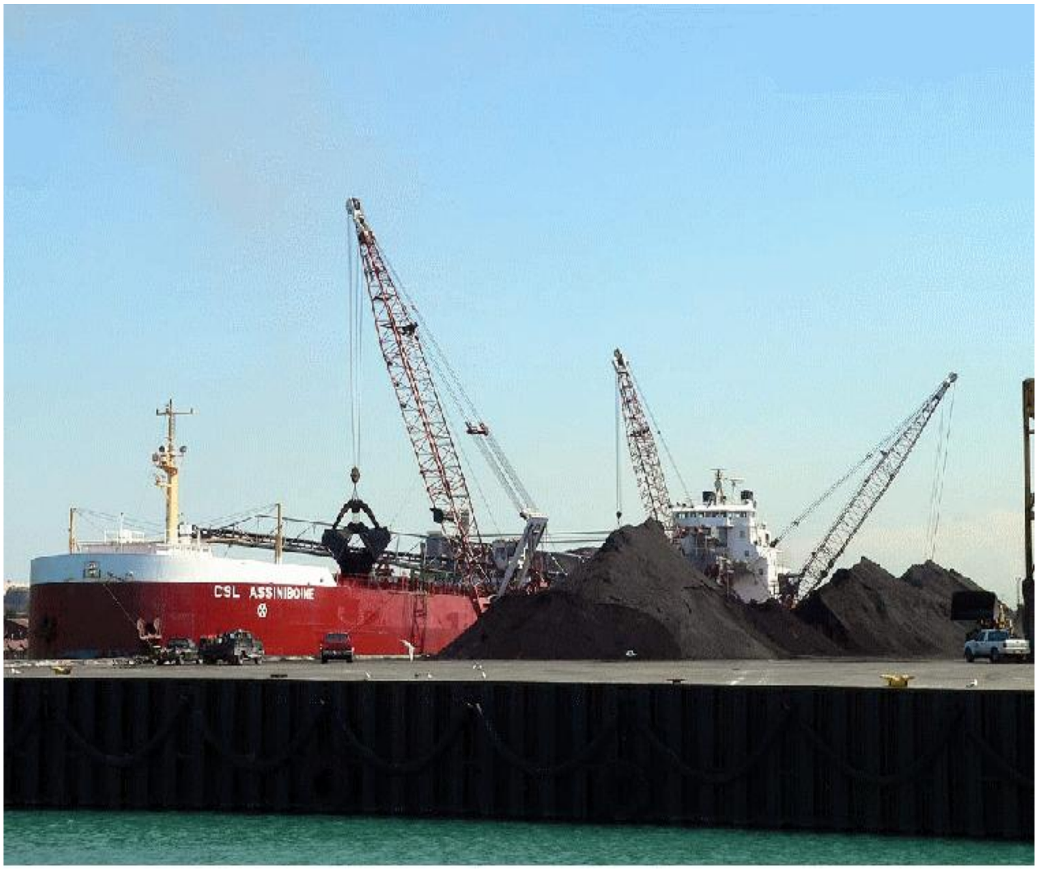


Coke Breeze

What is coke breeze?

Small particles from the coke oven that were once disposed of as waste but later were found to a good fuel for steaming purposes.

Combustion Engineering pages 2·21 and 2·22



Freighter being loaded with coke breeze

What is the difference between caking and coking coals?

Caking coals, when heated in the furnace, pass through a plastic state during which the individual pieces fuse together into large masses of semi-coke, which is impervious to flow of air. The air can pass only through cracks formed between the masses of semi-coke. The very active combustion in these cracks widens them into crater like fissures, which allow passage of a large volume of air, much of which is not used in combustion, while, in the centers of the masses of coke, the fuel remains inactive, owing to lack of air. The masses of coke must be broken with the fire tools or by the action of the stoker. For this reason, caking coals are burned on an underfeed type of stoker which has moving rams or other means for breaking the masses of semi-coke. Caking coals cannot be burned successfully on traveling grate stokers, because these stokers have no means for breaking the masses of semi-coke.

Coking coals are coals which make good coke, suitable for metallurgical purposes. Coke is produced when coking coal is heated in a coke oven, out of contact with air, and the greater part of the volatile matter is driven off. It consists mostly of fixed carbon and ash of the original coal. The term coking coals is sometimes used instead of caking coals. The caking process in a boiler furnace is confused with the coking process in the coke oven. There are many caking coals which do not make good coke in a coke oven, and there are free burning coals that make good coke. When we refer to the fusion of coal in a boiler furnace into large slabs or cakes, we say that the coal is caking. However, when we refer to the fusion of coal in a coke oven, we say it is good coking coal.

Blue Combustion Engineering page 2·22

Which coals cause difficulty in burning due to caking or agglomerating together?

The class of coals known as bituminous exhibit caking or agglomerating qualities.

Power Feb. 1974 page S-7

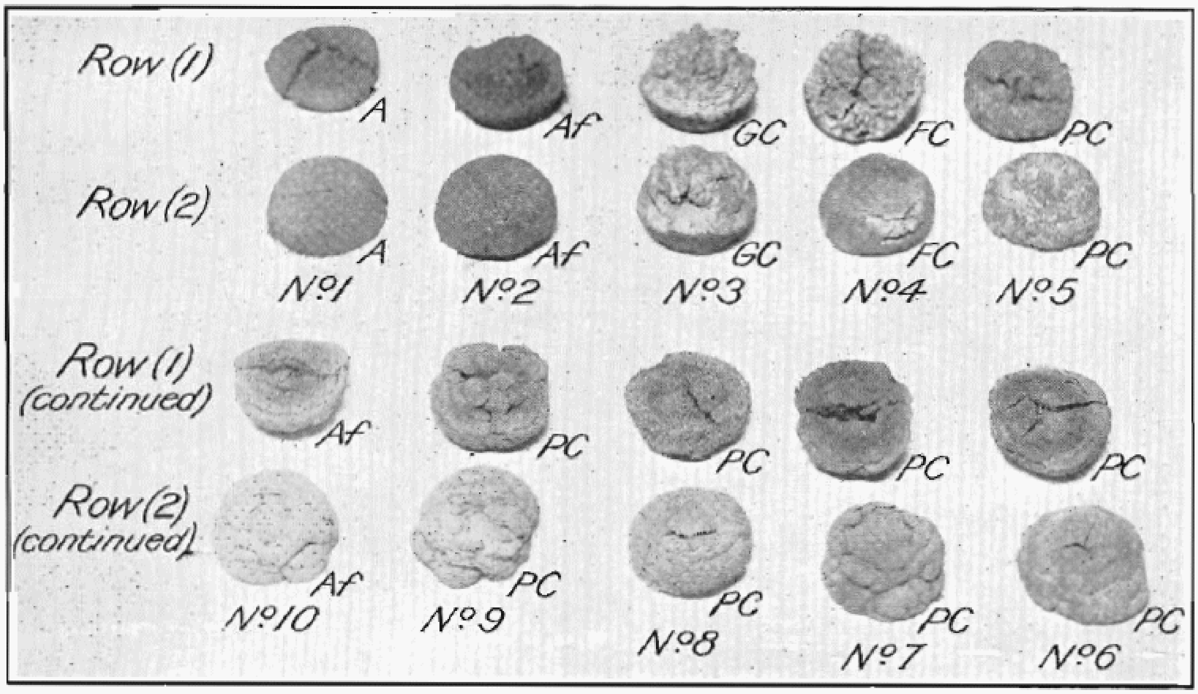
Is caking coal high or low in internal oxygen content?

Caking and coking coals have generally lower oxygen content then freeburning and non-coking coals. This however is true only to a certain extent. When a caking coal is exposed to the action of air over long periods of time, it picks up oxygen and loses much of its caking property. It is known that the outcrop coal of a caking coal seam shows little of the caking property. Outcrop coal is the exposed seam of an underground coal vein.

Blue Combustion Engineering page 2·22

Caking Coal

Outcrop coal in black band at top of cliff face shows non-caking properties



BUTTONS FROM THE VOLATILE-MATTER DETERMINATIONS CORRESPONDING WITH THE GRADINGS REPORTED

Row 1: Buttons are right side up.
Row 2: Buttons are upside down.

How can you determine if you have a caking coal or a free burning coal?

The coke button remaining from the proximate analysis is used to determine whether the fixed carbon residue tends to be caking or free burning. The coke button is subjected to a force of 500 gram weight carefully lowered upon it. If the button supports this weight without pulverizing, the coal is classified as "agglomerating", which is another name for caking. The results of ASTM test 720-57 for the free swelling index of coal may be used as an indication of the characteristic of the coal when burned as a fuel. Four 1 gram samples of pulverized coal are burned in special crucibles. The resulting coke buttons are compared with a series of 17 standard profiles numbered 1 through 9. If the residue is a powder or non-swollen (swelling index of 1 and pulverizes under a weight of 500 grams carefully lowered on it, the coal is designated as free burning or "nonagglomerating".

Detroit Edison Steam Course Fuels and Combustion page 3 Question #13

Agglutinating – value test is a small scale laboratory test that indicates the caking and coking properties of coal and gives an approximate measure of the material in coal that fuses and becomes plastic when heated. In this test, the average crushing strength of six specially prepared buttons, if within specified limitations, gives agglutinating –value index, reported to the nearest tenth of a kilogram.

Name two types of coal analysis.

There are two methods: the ultimate analysis splits up the fuel into all its component elements, solid or gaseous: and the proximate analysis determines only the fixed carbon, volatile matter, moisture and ash percentages. The ultimate analysis must be carried out in a properly equipped laboratory by a skilled chemist, but the proximate analysis can be made with fairly simple apparatus.

Proximate Analysis: Chemical analysis of a substance which determines the compounds of which it is composed, and the proportion of each, rather than the elements themselves and their proportions.

Boiler Room Questions & Answers by Alex Higgins page 58

Proximate Analysis.—The proximate analysis of coal as usually carried out includes the determination of moisture, volatile combustible matter, coke, "fixed carbon" and ash. The figures thus obtained give considerable information as to the geological age of the coal, determine its fitness for industrial uses and provide a basis for an approximate calculation of fuel value.

Quantitative analysis by Edward Garfield Mahin copyright 1914 page 253

Explain the proximate analysis and how to run the test.

The proximate analysis can be determined in a laboratory by a competent technician. In this analysis, the percentage of moisture, volatile matter, fixed carbon, and ash are obtained. This information is useful in predicting the behavior of the fuel when fired. A furnace designed for low volatile fuel would not be very efficient in burning high volatile fuel. Thus, the fuel and the fuel burning equipment must be matched to the furnace design for the best results.

The procedure for taking the proximate analysis is as follows:

1. Place a 1 gram sample of the coal to be tested in an oven that has been at 220 degrees Fahrenheit for one hour. Remove the sample and weigh it.
The difference in weight is the amount of moisture that has been removed.

2. The sample is then placed in a covered container and put into the oven, where the temperature is held at 1700° Fahrenheit, for seven minutes. The gas driven off is volatile matter. The sample is weighed again.

3. Remove the lid from the container and heat until the sample is completely burned. The difference in weight before and after burning is fixed carbon.

4. The residue left is called ash.

Steam Plant Operation by Woodruff and Lammers 5th edition page 110

The proximate analysis of a coal sample is a tedious procedure involving several separate weights and the handling of data from several sources. The 6750 Proximate Interface simplifies this process while weighing only 4.5 pounds and measuring 11 inches wide, 5 inches tall, and 9 inches deep,saving precious bench top space.

Which of the following cannot be found in a proximate analysis, ash, sulfur, or carbon?

sulfur

The proximate analysis is a method of evaluating coal quality. This test determines the amount of moisture, volatile matter, fixed carbon, ash, and heating value. Sulfur is found by use of the ultimate analysis.

Steam Plant Operation by Woodruff and Lammers 5th page 110

What is ultimate analysis?

The ultimate analysis requires a skilled technician or chemist to complete and exact the percentages of each of the combustible elements and other constituents that are reported. The elements to be tested are nitrogen, oxygen, carbon, ash, sulfur, and hydrogen. The first initial of each constituent spells "NO CASH" and is a common method used to remember the constituents.

Detroit Edison Steam Course, Fuels and Combustion page 9

Ultimate analysis is needed for the computation of air requirements, weight of products of combustion, and heat losses on boiler tests. The air requirements and the weight of products of combustion are used in the determination of fan size.

Blue Combustion Engineering page 2·8

Which coal analysis is the most representative of the true content?

The **ultimate analysis** gives the elements of which the coal substance is composed. These elements include carbon, hydrogen nitrogen, oxygen and sulfur. Ash content is determined as a whole, and when desirable separate analysis is made on the ash.

Blue Combustion Engineering page 2·3

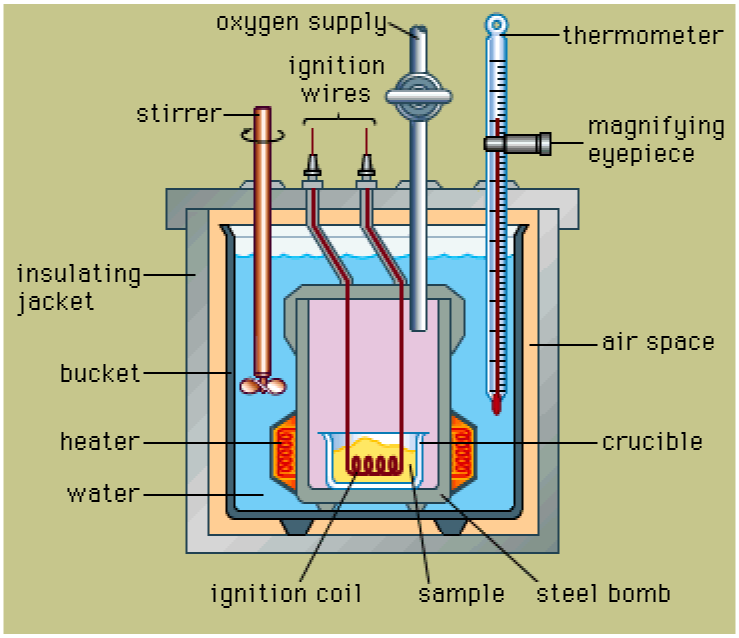
How is the BTU content of coal determined?

The heating value of coal may be determined by a bomb calorimeter. The bomb calorimeter provides a means of burning a small sample of coal under controlled conditions and measuring the resulting temperature rise in a given quantity of water. A 1 gram sample of pulverized and dried coal is placed in a tray. The tray is then placed in a steel bomb with a fuse wire arranged to extend into the tray of coal. The bomb is closed and connected to an oxygen tank and pressurized. A measured amount of water is poured into the calorimeter bucket. The bucket is placed in the calorimeter, and the bomb is carefully submerged in the water.

A stirring device agitates the water to maintain uniform temperature. A calibrated thermometer permits the operator to observe the temperature. The coal is ignited by means of the fuse wire and the temperature rise noted.

The BTU of the coal is found by multiplying the temperature rise by a constant for the specific calorimeter.

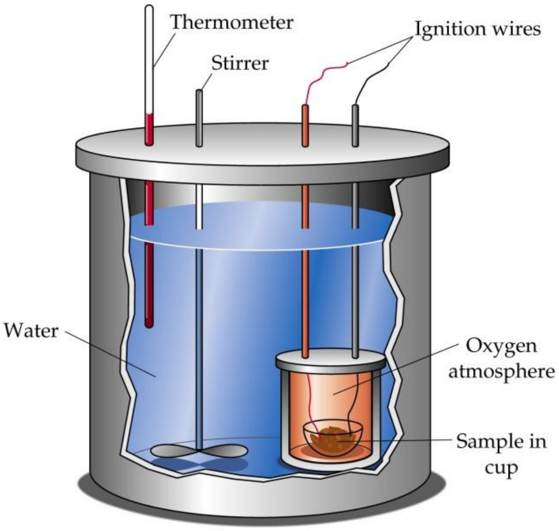
Steam Plant Operation by Woodruff & Lammers page 110

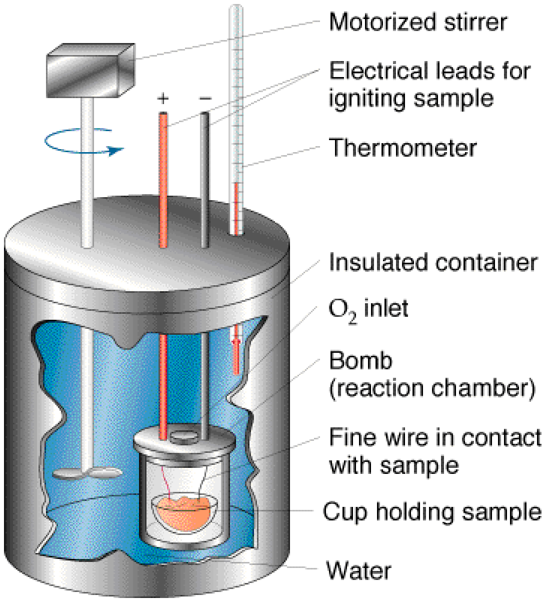


What is a bomb calorimeter and how is it used?

The heating values of liquid and solid fuels are accurately determined by a device called a bomb calorimeter. The bomb will be placed in a container that contains a known amount of water before being ignited. A one gram weight of fuel (air dried and pulverized, if coal) is placed in a cup suspended from the cover of the bomb and an insulated wire electrode is inserted to make contact with the fuel. The bomb is assembled and charged with oxygen to approximately 400 psi, to insure sufficient oxygen for complete combustion. The bomb is then placed in a container and covered with a known quantity of water and ignited. The water surrounding the bomb is agitated while the fuel is burning and the temperature rise, of the water, is carefully recorded. Allowances for radiation, heat from the ignition current, are compensated for, and heat gained by the temperature rise of the water must equal the heat given up by the fuel. When this value is known, then the heating value of the fuel may be computed. Determining the heating value of a gaseous fuel, with a bomb calorimeter, requires a different hookup, with a continuous, flow of fuel, through the bomb. This procedure is very complex and requires the service of a skilled chemist.

Detroit Edison Steam Course, Fuels and Combustion page 11





Describe an oxygen bomb fuel calorimeter.

The calorimeter has a porcelain or gold-lined steel bomb having a tight fitting cover screwed into place. Within the bomb is a small platinum pan for holding the fuel. Two electrodes, connected at their lower end by a fuse wire, extend through the cover of the bomb, and connect the fuse wire to an electrical circuit containing a suitable switch and a 12-volt battery. The bomb sets into a calorimeter that contains a definite weighed amount of water. A stirring device for agitating the water within the calorimeter is attached to a support connected to the outside of the apparatus. The temperature of the water in the calorimeter is shown by an accurate thermometer graduated to read to one-thousandth of a degree. The calorimeter and bomb are surrounded by an outer vessel covered with asbestos and filled with water at a temperature slightly higher than the surrounding atmosphere. This outer vessel maintains constant conditions and makes the determination of the radiation loss more accurate. An oxygen tank supplies the oxygen required to burn the fuel, and a pressure gauge attached to the oxygen tank piping is used to determine the pressure of the oxygen entering the bomb.

Elementary Steam Power Engineering by Edgar MacNaughton 3rd edition pages 142-143.

What is the difference between "as received" and "as fired" coal?

Method of reporting analysis may be expressed in terms of:

1. coal "as received" or "as fired"
2. coal "moisture free" or "dry"
3. coal "moisture-and-ash-free" or "combustible"

The first term under each method is that used by the Bureau of Mines, and the second that used in the A.S.M.E. testing code. Engineers prefer to have the analysis expressed for coal "as fired", since it represents the condition of the coal as fed to the furnace. The dry-coal basis is however, generally used for reporting analysis, as it excludes the moisture, which is principally due to weather conditions during shipment. A better idea as to the value of the coal can be obtained with the moisture excluded. Coal "as fired" is in the same condition as when it comes from the bunkers. The analysis on dry-coal basis is found from the analysis "as fired", by dividing each constituent by 1 - the proportional weight of moisture. The analysis on combustible basis is found by dividing the analysis "as fired" by 1 – the proportional weight of ash plus moisture.

McNaughton Elementary Steam Power Engineering 3rd edition pages 115-116

The as-received analysis of a fuel represents the actual proportions of the constituents in the fuel sample as received at the laboratory. The sample itself may be fuel as-fired, as-mined, or in any other given condition.

Blue Combustion Engineering page 2·3

The heating value of a solid fuel is expressed in Btu per lb of fuel on as-received, dry, or moisture-and ash-free basis. Heating values as determined in calorimeters are termed higher or gross heating values, and include the latent heat of the water vapor in the products of combustion. In actual operation of boilers, the water vapor in the waste gas is not cooled below its dewpoint, and this latent heat is not available for making steam. The latent heat is sometimes subtracted from the higher, or gross, heating value to give the lower, or net, heating value. This deduction in Btu per lb of fuel is equal to the total pounds of water vapor per pound of fuel (moisture in the fuel, plus vapor formed by combustion of hydrogen of the coal substance) multiplied by the latent heat of evaporation at the partial pressure of the vapor in the exit gas. The value used varies from 1040 to 1080 Btu per lb of water vapor. Lower heating values are standard in European practice, and higher heating values are standard in American practice.

Blue Combustion Engineering page 2·6

Which of the three coal analyses is most representative of true coal content; As received, as fired, or moisture and ash free?

Moisture and ash free. Coal analyses are expressed in three different ways, depending upon the constituents included. The designation "as received" or "as fired" refers to the analysis in which the actual moisture is included. When the expression "moisture-free" or "dry coal" is used, the analysis considers the moisture as having been removed. Since neither moisture nor ash adds to the heating value of coal, analyses are calculated to exclude these constituents and in this way give a true indication of the nature of the combustible material. When the moisture and ash are not included, the analysis is referred to as "moisture and ash free" or "combustible."

Steam Plant Operation by Woodruff and Lammers 5th edition page 110

Describe the difference between the high and low value of fuel.

The "higher" heat value is that determined by the calorimeter, and should be used in all boiler test calculations. The "lower" heat value is the higher heat value less a correction for the heat loss in the escaping steam formed from the moisture in the coal.

Elementary Steam Power Engineering by Edgar MacNaughton 3rd edition page 144

Steam out the stack

What percent of carbon is typically found in coal?

On a moisture, sulfur, and ash free basis

a. Lignite..........................	66%
b. Bituminous.................	82%
c. Semi-bituminous.........	86%
d. Anthracite...................	93 %

On an as received basis:

	Proximate	Ultimate
a. Lignite......................	16-35%.......................	32-51%
b. Bituminous.............	36-63%.......................	54-81%
c. Semi-bituminous.....	63-76%.......................	71-84%
d. Anthracite...............	76-88%.......................	78-86%

Steam Power Plant Engineering 6th edition Gebhardt page 38- 40 Table 2 as compiled from the Bureau of Mines Bulletins

What is the carbon content of anthracite?

Anthracite is commonly called hard coal. It is very dense. Its specific gravity is high. It has a metallic luster. It burns with a short yellowish-blue flame and without smoke. It is largely carbon. Analyses of various grades (air-dry) show an average of about 83.5 percent fixed carbon 3.2 percent volatile matter, 10.5 percent ash and 2.8 percent moisture.

Croft steam boilers page 217

Carbon in anthracite coal is 79.4% to 83.7%.

Kent's 12th edition page 2-26

Fixed carbon in anthracite coal ranges from 86 to 98 percent

Steam Plant Operation by Woodruff and Lammers 8th edition page 201

Anthracite coal

What percent of moisture is typically found in coal?

The total moisture content of coal consists of equilibrium moisture and surface or free moisture. Equilibrium moisture varies with coal type or rank and mine location, and would more accurately be called "bed" or "seam" moisture. In reality, surface moisture is the difference between the total moisture and the "bed" moisture.

There is no such thing as a typical percentage of moisture for coal. It ranges for "seam" moisture:

Bituminous:

Low Volatile	2%
Medium Volatile	2%
High Volatile A	4%
High Volatile B	7%
High Volatile C	10%

Sub-bituminous:

A	14%
B	19%
C	25%

Lignite:................................ 40%

Power Plant Engineering page 1.159

How much water is formed when one pound of coal is burned completely?

a. Lignite	.43 lb/lb
b. Bituminous	.52 lb/lb
c. Anthracite	.28 lb/lb

Kent’s 12th edition pages 2.04 and 2.05 Table 1

A pound of bituminous coal when burned to complete combustion will produce how much water?

0.52 lb of water per lb of coal. This is based on an average of 27 medium and high volatile bituminous coals.

Kent’s 12th edition page 2-05 Table 1

What is spontaneous combustion?

Coal storage frequently presents a problem because the coal can overheat and start to burn, resulting in spontaneous combustion.

Some precautions are:

1. Measure the coal's temperature using a thermometer or thermocouple inserted in a pointed pipe.

2. In outside areas, use a storage method that prevents segregation: Pack the coal tightly to exclude air.

3. Prevent direct radiation of heat (boiler) against the side of bunkers by providing an insulating air space between the inner and outer bunker walls.

4. Do not allow a "dead" storage of coal to remain in excess of one month in an overhead bunker.

5. Should the temperature exceed 150º Fahrenheit, inject CO_2 (carbon dioxide) gas at once, by using a perforated tube inserted into the coal. Then move the coal as soon as possible.

Steam Plant Operation by Woodruff and Lammers 4th edition page 125

The process of spontaneous heating is operative at room temperature as soon as freshly broken coal is exposed to air. It begins with the physical absorption of oxygen and is continued by the formation of a solid chemical compound of coal and oxygen which is gradually decomposed as the temperature rises. The coal increases in weight by the amount of oxygen retained. There follows the breaking up of the solid compound of coal and oxygen and the formation of the final oxidation products - CO_2, CO, and H_2O). This process generates heat. Generally speaking, coals of lowest rank, such as sub-bituminous and lignite, are most susceptible to spontaneous combustion. The reaction between coal and oxygen is considered to double for about each 15 degree degrees Fahrenheit rise. The total exposed surface is an important factor: greater the surface, the more chance of oxidation.

Kent's 12^{th} page 2-33

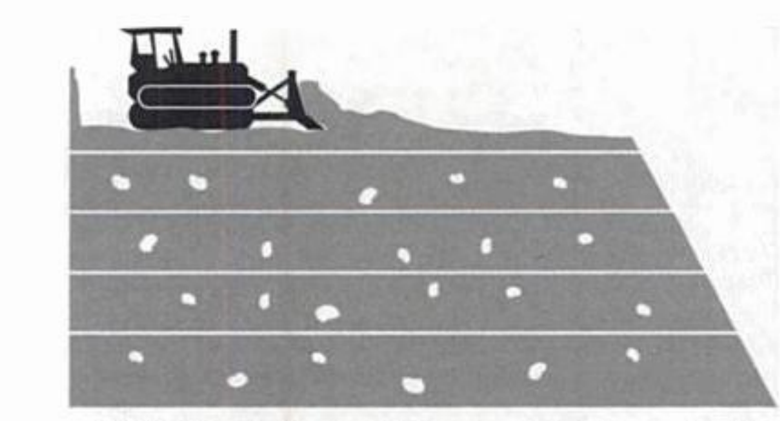
Coal pile smoldering

Large coal pile smoldering

Describe how to build and maintain a stored pile of coal so that spontaneous combustion is kept to a minimum.

A well built coal pile will be on a well drained area, free of standing water. Making certain that the ground is solid and level. Build up the pile in successive layers, each not more than 2 feet thick. Constant coal piles in a rounded or pyramid shape, with the steepest slopes possible, to prevent rain or melting snow and ice accumulating and penetrating into the pile. Make periodic temperature checks of the pile, particularly at the edges and side slopes. Seal the pile as much as possible. A 6 inch layer of fines, anchored against wind erosion by a carefully placed coarse layer is good. Shove aside the top layer of coal when reclaiming, and select the drier coal from underneath. As soon as the coal is reclaimed, refill the hole. Keep coal in good condition. After every rain, rework the coal pile to remove gullies, pockets and rivulets.

POWER Feb. 1974 Page S-l9



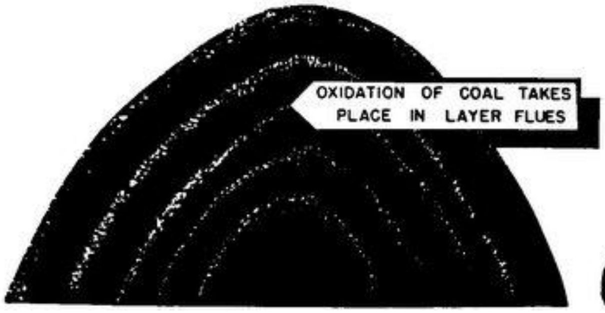
Bulldozer compacting the coal pile in layers

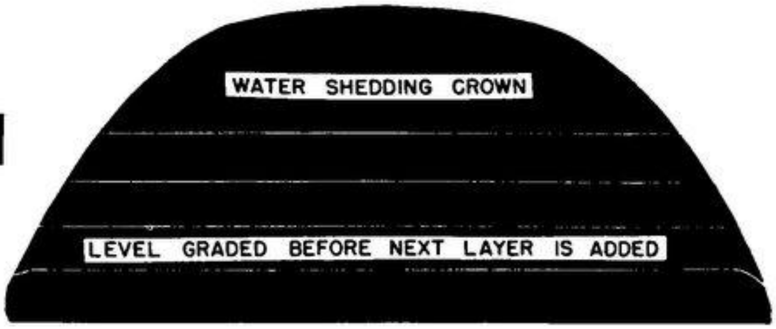
Bulldozer compacting the pile by running over the top of it with the treads of the tracks

Name ways of storing coal that will help prevent spontaneous combustion.

Methods of storing coal that will lessen or prevent spontaneous heating are:
a. Submerge the coal in water.
b. Layer and compact the pile with a bulldozer or similar device
c. Store in shallow piles, not deeper than 6 to 8 ft.
d. Store coal in a silo or bunker.
e. Store screened, large size coal
f. Keep storage area free of extraneous material
g. Avoid drafts of air through the pile
h. Use older storage first

Kent’s 12th edition page 2 – 33





How would you stack an outdoor coal pile?

The best defense against segregation is layer piling. When bituminous coals are stored, the pile should be built in layers of 1 to 2 feet thick, and each layer should be thoroughly packed to a density of 65 to 72 lb/ft^3, to eliminate air spaces. The top of the pile is formed in a slightly crowned fashion and is made symmetric, to permit runoff of water. The sides and tops are covered with 1 ft. of compact fines and capped with a 1 ft. layer of sized lump coal.

Sub-bituminous and lignite coals should be stockpiled in the same manner, but with thinner layers - not more than 1 ft. thick. The top and sides can be covered with slack sized coal prior to compaction. Snow fences can be placed across the pile normal to the direction of the prevailing winds, which helps prevent the drifting of fines that can cause spontaneous combustion.

Power Plant Engineering page 3.33

A well built coal pile will be on a well-drained area, free of standing water. Making certain that the ground is solid and level. Build up the pile in successive layers, each not more than 2 ft. thick. Constant coal piles in a rounded or pyramid shape, with the steepest slopes possible, to prevent rain or melting snow and ice accumulating and penetrating into the pile. Make periodic temperature checks of the pile, particularly at the edges and side slopes. Seal the pile as much as possible. A 6 in. layer of fines, anchored against wind erosion by a carefully placed coarse layer is good. Shove aside the top layer of coal when reclaiming, and select the drier coal from underneath. As soon as the coal is reclaimed, refill the hole. Keep the coal in good condition. After every rain, rework the coal pile to remove gullies, pockets and rivulets.

Power Feb. 1974. page S-l9.

Name the things you watch for when storing coal?

In reserve storage where the coal will be stocked for extended periods of time in open air, two problems must be considered. First, the coal will deteriorate, lose heating value, by weathering. Second, there is an ever-present danger of spontaneous combustion. Coal that is exposed to atmospheric air oxidizes slowly, releasing gasses. This loss reduces the heat value of the coal, usually at the rate of about 1% per year. If release of gasses takes place within the stock, gasses (mostly methane) accumulate. If this action produces heat and it is not ventilated, it will gradually raise the temperature until the methane ignition point is reached and fire begins.

I.U.O.E., Fuels, Oils and Lubricants, page 6-3-6

Two Caterpillar D9's working to spread and compact the coal pile

What effect does weather have on stored coal?

As the coal is wetted and dried by exposure to weather, some of it will disintegrate. Lower rank coals are most susceptible to weathering. This disintegration, termed "weathering or slacking", reduces the heat content of the coal, because of a loss of volatile matter. Coals disintegrate readily in storage exposing more surface area for oxidation.

Detroit Edison Steam Course Fuels and Combustion. page 4 Question #17.

What is "slacking"?

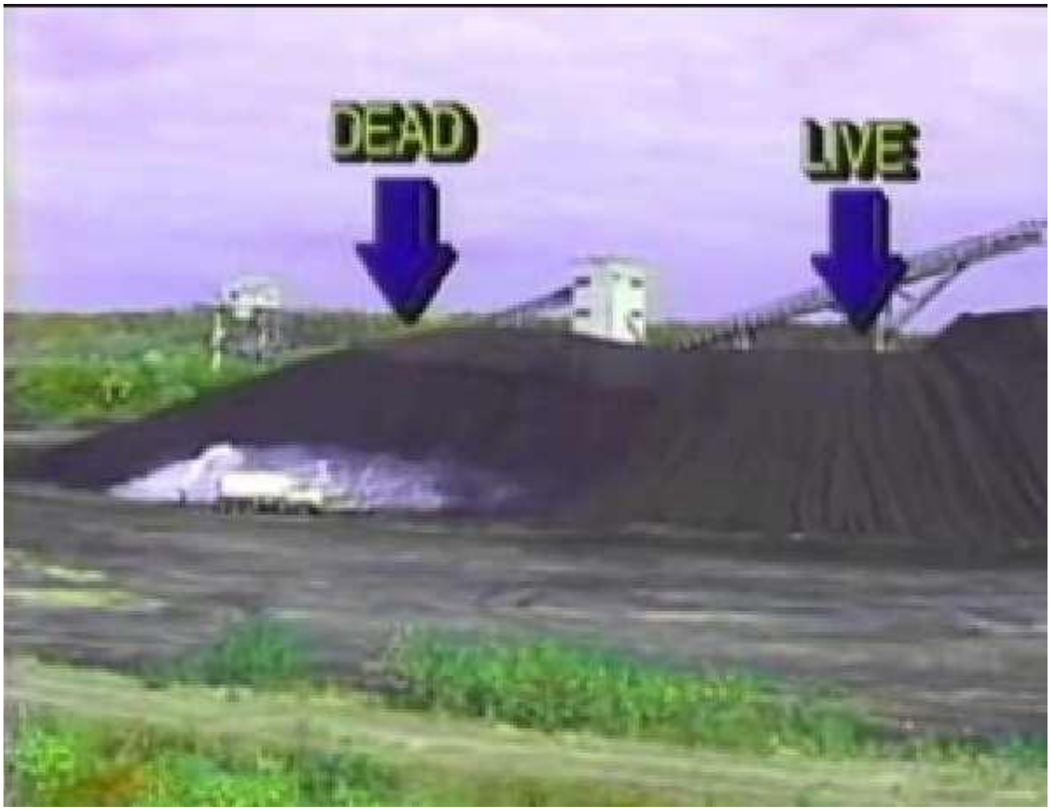
Slacking refers to the disintegration of coal due to exposure to the elements. This disintegration reduces the coal to virtual dust, allowing it to be carried away by the wind. This is a costly problem, especially if the coal is being shipped by rail. The coal is purchased by the ton from the mine, if slacking takes place en route less coal will arrive than was purchased.

Detroit Edison Steam Course Fuels and Combustion. page 4 Question #17

What is the difference between dead coal storage and live coal storage?

Coal storage can be divided into two categories according to purpose: Live (active) storage, which supplies firing equipment directly, and Dead (reserve) storage which is used to guard against delays in shipments.

Power Feb. 1974. page S-17



The dead coal storage is being sprayed with Soil Sement which forms an impervious membrane to prevent oxygen and water infiltration.

What is the maximum temperature safely allowed during coal storage?

Arrangements should be made to check the temperature of stored coal frequently. If thermometers are not available, an iron rod forced into the pile and removed after a short period of time will give a good indication of a hot pile if the rod cannot be held in your hand. When temperatures above 120 degrees Fahrenheit are discovered, it is advisable to move the hot coal.

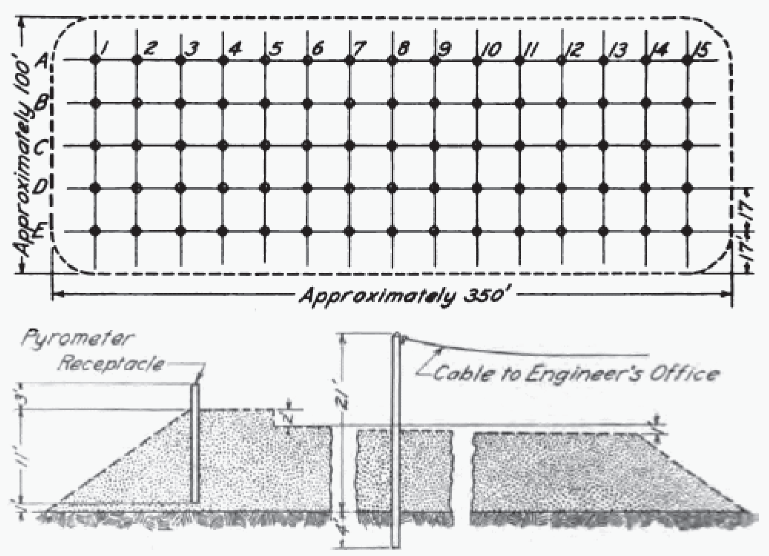
Kent’s 12th edition page 2-33

Stockpile temperatures should be monitored, as by using thermometers set in pipes in the stockpile or by using probes. Temperatures of 160º Fahrenheit and above indicate approaching fire. In that event, measures that should be taken include recompacting to try to seal off the air supply if combustion has not yet begun, injection of CO_2 as an extinguishing medium, or digging out the affected coal.

I.U.O.E. Fuels, Oils and Lubricants page 6-3-6

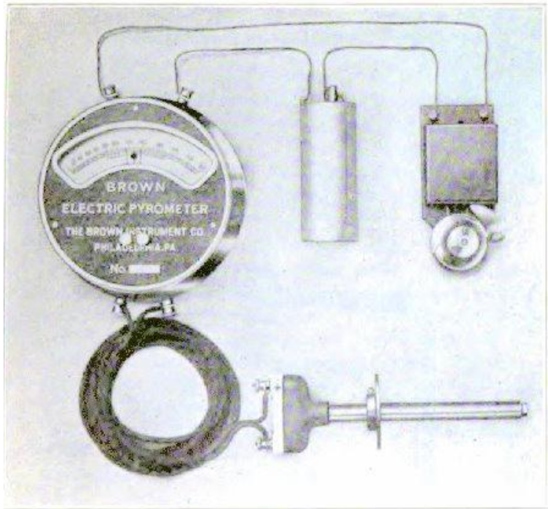
Should the temperature exceed 150º Fahrenheit, inject CO_2 gas at once, by use of a perforated pipe driven into the coal.

Steam Plant Operation by Woodruff & Lammers 3rd Edition pages 112-113



PLAN AND SECTION OF COAL PILE SHOWING ARRANGEMENT OF RECEPTACLES FOR PYROMETERS

Driving iron pipes into the coal pile and placing pyrometers to monitor coal pile tempera**tures**



INDICATING PYROMETER WITH ALARM ATTACHMENT

INDICATING THERMOMETER — LONG DISTANCE TYPE

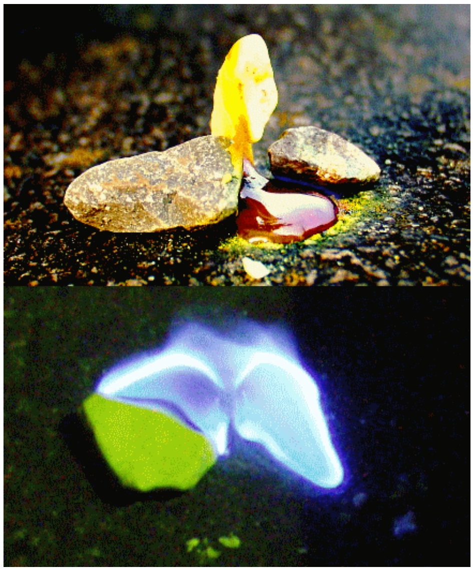
What elements cause problems in coal storage?

The fire hazard of coals high in moisture and sulphur content is great.

Blue Combustion Engineering, page 2·20

High moisture content may create handling problems. During the winter months, moisture may freeze in transit making it difficult to remove the coal from railroad cars. There is no simple method to unload the frozen coal. Coals removed from a storage pile during snowy or rainy weather also may contain a high percentage of moisture, which adheres to the chutes and may not flow to the stoker or pulverizer mill.

I.U.O.E., Fuels, Oils, and Lubricants, page 6-1-22



Upper photo shows sulfur burning in daylight, the
Lower photo shows sulfur burning at night

How would you tell if the coal pile is starting to burn?

If air enters the coal pile, approximately the same amount of gas must escape somewhere through the topage. On a cool morning, the escaping gas is indicated by a haze of steam. These steamy places are the leaky spots in the coal pile surface, where the coal-dust covering is imperfect. These leaky spots can be eliminated by additional packing and dust covering. Temperature probes in the coal pile and visible smoke are signs that a fire is occurring in the coal pile.

Blue Combustion Engineering, page 2·20

Hot spots also can be located by probing the pile with a steel rod. If the section of rod withdrawn from the pile is too hot to hold by hand then you have a problem. (150 to 160 degrees Fahrenheit)

Power Feb. 1974 pgs. S-18. S-l9

How can you tell if a coal pile is starting to burn and what do you do if the coal pile is burning?

Heated areas can be spotted in wet weather by rapid drying and a lighter color of the surface coal. On a cold or humid day, streams of vapor and the odor of gas are signs of heating or of air entering the pile. Hot spots also can be located by probing the pile with a steel rod. If the section of rod withdrawn from the pile is too hot to hold by hand then you have a problem. (150 to 160 degrees Fahrenheit)

1. Cut away or isolate heated coal
2. Recompact the pile, starting at edges and working inward
3. Move coal and respread it, if area permits
4. Try feeding carbon dioxide into pile, using pipe fitted with well drilling points

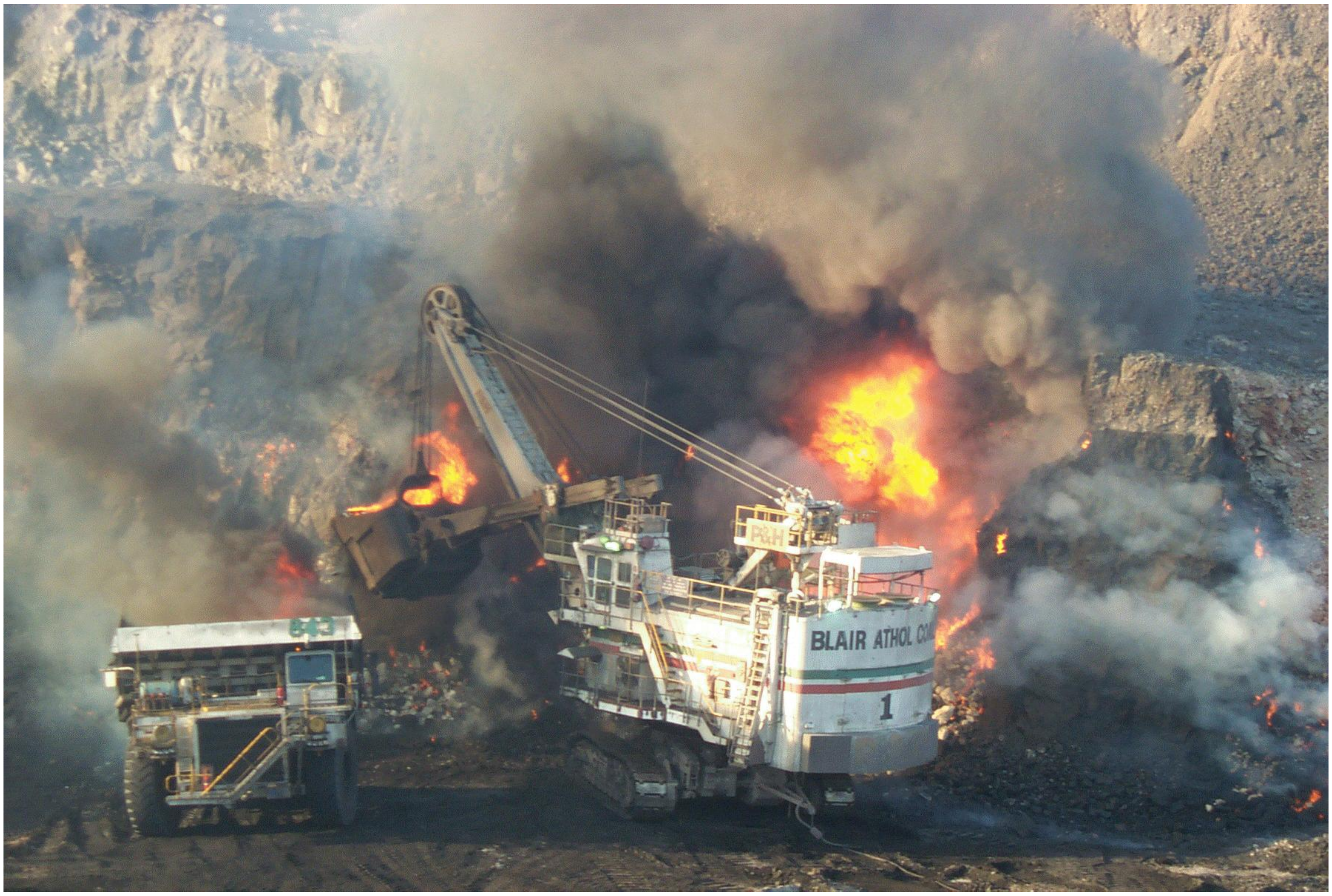
In cutting away heated coal, do not disturb remaining pile. **Caution:** Do not use water on heated area. It might quench the fire, but it will also set up conditions likely to produce a reoccurrence of the heating within a short period of time.

POWER Feb. 1974 pages S-18 and S-l9

Temperatures of 160 degrees Fahrenheit and above indicate approaching fire. At 160 degrees Fahrenheit, oxidation increases rapidly. If a fire is discovered a perforated pipe can be driven into the pile and CO_2 injected into the pipe. Then compact the pile so that no oxygen can penetrate the pile. If this doesn't work then the coal pile should be moved and the effected coal spread out on the ground.

I.U.O.E. Fuels, Oils and Lubricants page 6.3.6

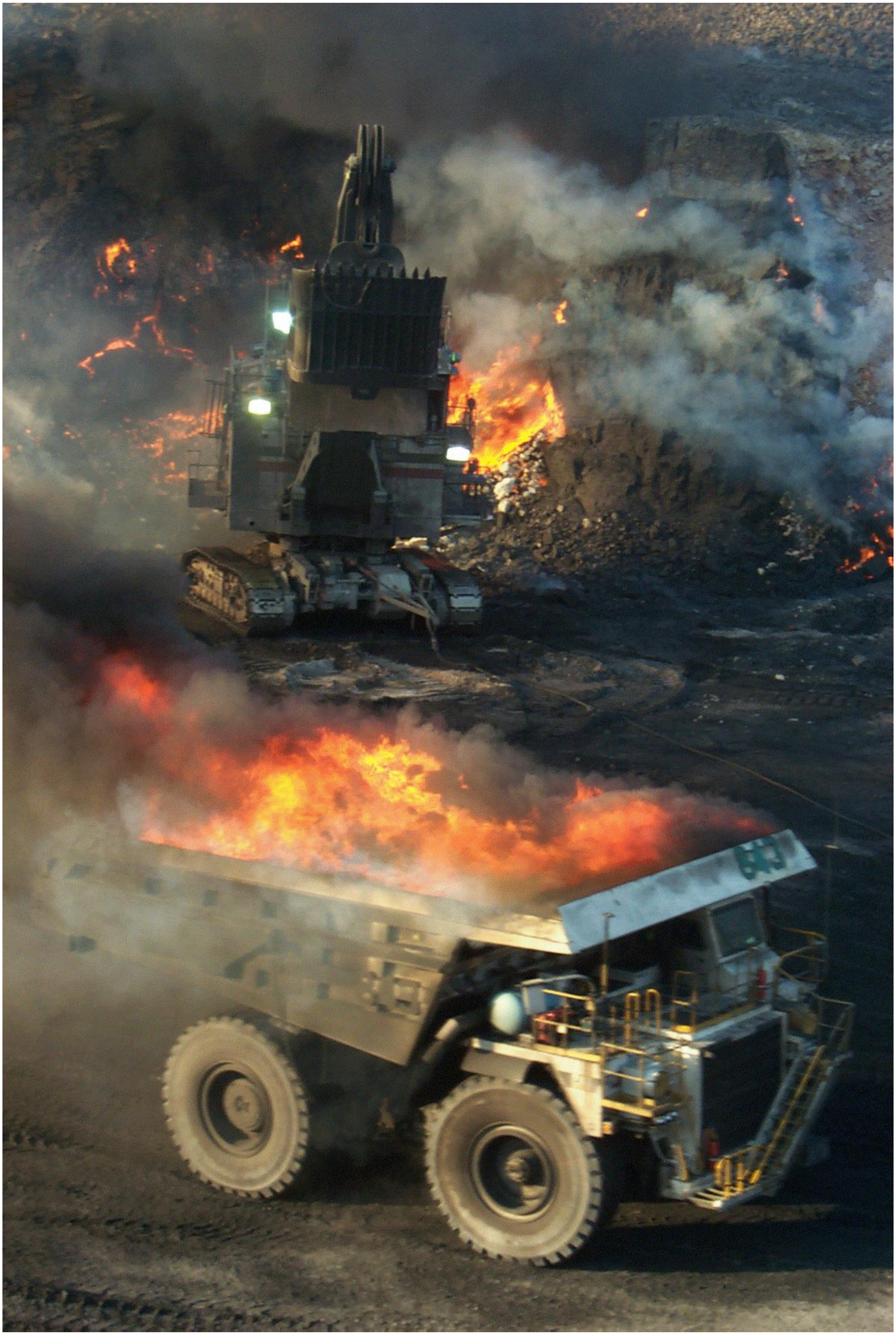
Blair Athol Coal Mine at Clermont, New South Wales, Australia. On Jan 14th, 2004



The first indications of a problem with heating were when overburden in strip 16 east of the open-cut was drilled and blasted in July 1999. A significant fire started in exposed coal at the end of the strip. This fire was successfully smothered with overburden and it was assumed that, when exposed, any heating in the old workings could be treated in the usual fashion. However, as the dragline began to uncover the coal it became clear that the heating in this area would be of a much larger scale to that experienced before.

Another coal fire at another surface mine

The dump truck hauls the burning coal away from the coal seam.



Blair Athol Coal Mine digging out the coal on fire and trucking it away from the coal seam

When storing coal in a hopper, what concerns must we take?

A hopper that has pockets or "dead area" is difficult to empty completely. This can result in spontaneous combustion and corrosion. Temperatures must be monitored and periodic inspections must be must be made on the inner surfaces of the hopper for corrosion due to sulphur content and wet coal mixture.

I.U.O.E. Fuels, Oils and Lubricants 6-3-5

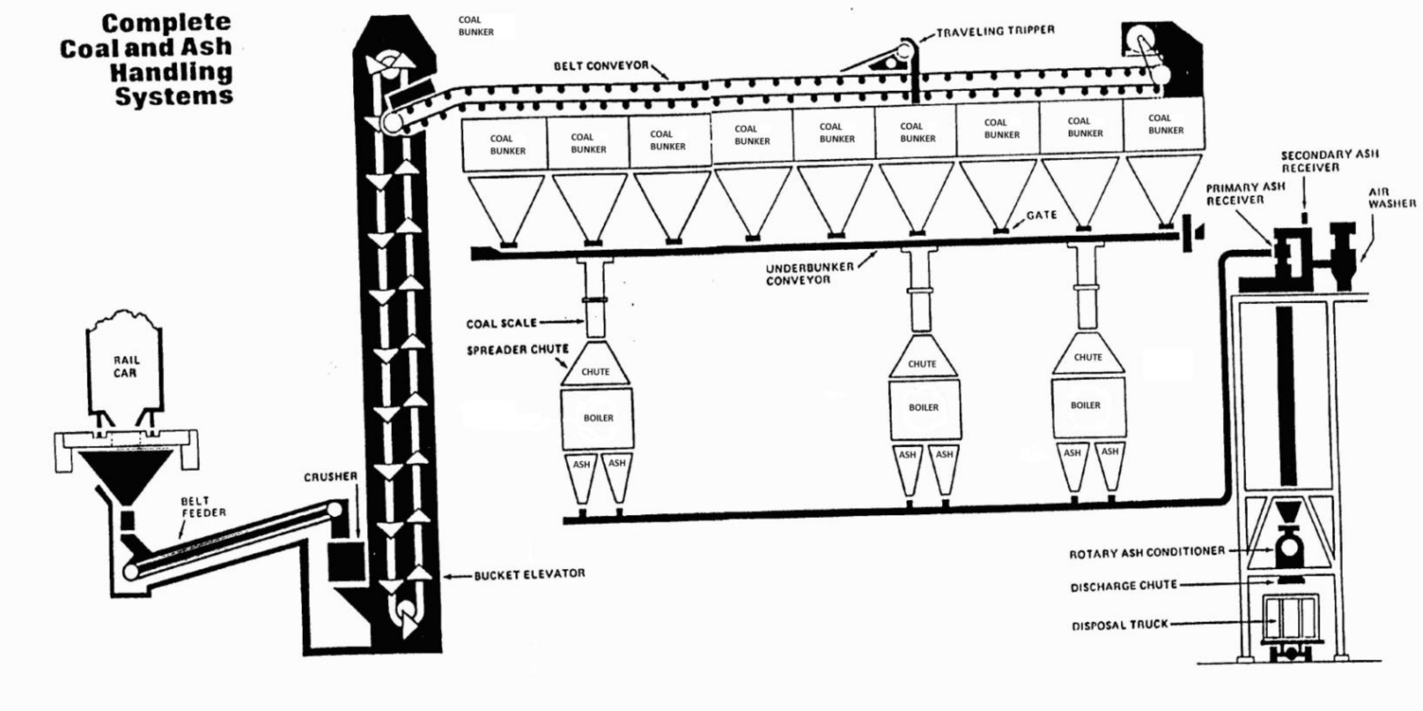
How do you put out a fire in a coal bunker?

In the event that a fire does occur, it should be handled immediately. The most effective technique is to evacuate all the coal in the bunker as quickly as possible, running the hot coal through the fuel burning equipment until the bunker is empty. No raw coal should be discharged into the bunker until all the burning coal is removed. All fuel handling equipment should be watched closely during the procedure. All valves connected with a pulverizer should be closed to prevent a draft through the pulverizer. With stoker-fired units, a continuous flow to the stoker hopper should be maintained so the chute is sealed. This prevents an air flow back into the bunker. Other methods dig out the burning coal and setting it aside, to let it burn itself out.

I.U.O.E., Fuels, Oils, and Lubricants page 6-3-6

At General Motors Poletown Plant in Detroit, there is a conveyor system under the bunkers between the bunkers and the spreader stoker hoppers known as an underbunker conveyor. This conveyor extends through an opening in the outside wall and burning coal can be conveyed outside in an emergency.

Plant tour



This illustration shows a railcar dumping coal on the left to an underground belt feeder that drops the coal onto a crusher. From the crusher the bucket elevator brings the coal up several stories until it is above the coal bunkers. The belt conveyor on top has a traveling tripper that determines which coal bunker gets the coal. The Operator determines which spreader stoker hopper gets the coal by the use of the underbunker conveyor and another tripper which is not shown. This system is used in place of the older weigh larry system that had a traveling hopper under the bunkers. You would fill the weigh larry and then run on a track above the individual hoppers to fill each hopper in turn.

What is the "angle of repose"?

The "angle of repose" is the angle in relation to the horizontal at which material will stand when piled.

Kent's 12th edition page 2-32

What is the "angle of repose" for Anthracite and Bituminous?

Anthracite = 30 degrees
Bituminous = 45 degrees

These numbers are considered normal but can vary according to:

a. Size and shape of coal.
b. Percentage of undersize coal
c. Moisture content.
d. Method of piling.

Kent's 12th edition page 2-32

Why is angle of repose important?

Coal pile edge erosion and oxygen accessibility vary directly to the "angle of repose". This would be a concern because of spontaneous combustion.

What is the "sliding angle" of coal on bright steel?

anthracite........................18 degrees
bituminous.....................22 degrees
coke.................................24 degrees

Note: Chutes should be 45 degrees or greater to prevent hang-ups of coal not sliding by gravity out of a silo or other container.

Kent's 12th page 2-32

What is the government standard for unsatisfactory coal shipments?

If coal of three or more consecutive deliveries, or of deliveries aggregating 10 per cent or more of the contracted quantity proves to be unsatisfactory in the use for which it may have been purchased, although all the other conditions of the contract may have been met by the contractor, the government may at its option :

(a) decline to accept additional coal from the mine
(b) terminate the contract without liability

Kent's 12th page 2-25

Give BTU values for:

Anthracite............. 13300 BTU/lb (Woodruff & Lammers 8th edition page 200)
12700 BTU/lb (I.U.O.E. Fuels, Oils, & Lubricants)

Bituminous............ 13900 BTU/lb (Woodruff & Lammers 8th edition page 200)
11000-14000 BTU/lb, (I.U.O.E. Fuels, Oils, & Lubricants)

Sub-Bituminous..... 9400 BTU/lb, (Woodruff & Lammers 8th edition page 200)
8300-13000 BTU/lb (I.U.O.E. Fuels, Oils, & Lubricants)

Lignite................ 7100 BTU/lb (Woodruff & Lammers 8th edition page 200)
8300 BTU/lb, (I.U.O.E. Fuels, Oils, & Lubricants)

What is ash?

Ash consists of an enormous variety of mineral species in coal, encompassing the entire spectrum of major mineral forms found in the earth’s crust.

Most of these minerals fall into one of several groups: clay minerals (aluminosilicates), sulfides/sulfates, carbonates, chlorides, silica/silicates and oxides.

Bituminous coals typically have higher levels of silica, aluminum and iron, while the lower rank sub-bituminous coals and lignites generally have higher levels of the alkaline earth metals, calcium and magnesium, and the alkali metal sodium.

A principal source of iron oxide is pyrite $FeS_{2.}$ which is oxidized to form FeO_3 and sulfur oxides.

In a boiler furnace pulverized coal is burned in suspension. During combustion ash particles are exposed to temperatures as high as 3000 degrees Fahrenheit and a variety of heating and cooling rates. The atmosphere in the burner zone can range from highly oxidizing to highly reducing. Depending on the composition of the particular particle, mineral forms in the ash can react with each other, with the organic and inorganic constituents of the coal, and with gaseous elements such as sulfur dioxide $SO_{2.}$ in the flue gas. The compounds that are ultimately formed cause deposition problems. The compounds can have a wide variety of melting temperatures and viscosity-temperature characteristics. Particles that melt at lower temperature and stay sticky long enough to reach a furnace wall become slag deposits.

Babcock & Wilcox "Steam its Generation and Use" 40th edition page 20-4

What is the fusion point of ash in an average coal fired plant?

Around 2100º degrees Fahrenheit

From 2030º to 2200º Fahrenheit

Combustion Fossil Power page 7-3

When the fusion temperature of the ash is higher, can higher rates of combustion be reached or does fusion temperature matter?

It is important to analyze the fusing or melting temperature of the ash or coal. When low fusing temperature ash is exposed to high temperature zones of a fuel bed, hard clinkers will form. These clinkers interfere with the movement of fuel in a stoker and make it difficult to clean a hand fired grate. This results in an increased amount of carbon being removed with the ash, uneven fuel bed with increased excess air, and burned out grates or stoker castings. Molten ash in pulverized fuel fired furnaces and in some stokers is carried to the walls and into the boiler passes by the gasses where it accumulates in large quantities. This molten ash reacts with and may cause rapid deterioration of the refractory furnace lining. When the melting temperature of the ash is low, it is sometimes necessary to operate the boiler at reduced ratings or with increased excess air to lower furnace temperatures and so prevent formation of slag.

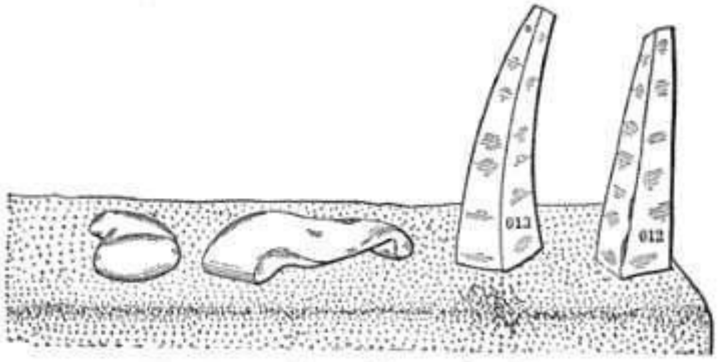
I.U.O.E. Fuels, Oils, and Lubricants pages 6-1-22 and 6-1-23

How do you tell the fusing temperature of ash?

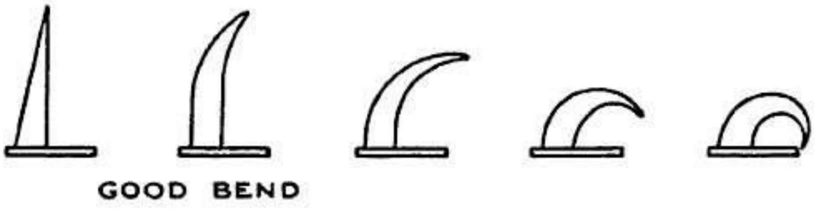
Usually five cones are mounted on a base, and ignited at a dull red heat for 30 minutes in an open muffle to remove carbonaceous material. The test piece is placed in the muffle furnace in the position shown, the loosely fitting cover is added, and the gas is burned about 10 minutes before the top cover plate is put on. The flow is then regulated to cause combustion to take place just above the tuyere and yet maintain a yellowish flame at least 6 inch above the opening in the furnace cover plate. After reaching 800 degrees Celsius, the temperature is increased at a rate of from 5 to 10 degrees Celsius per minute, maintaining the 6 inch reducing flame until at least 1450 degrees Celsius is reached. The following temperatures are noted for each sample:

1. Initial deformation, when the first rounding or bending of the apex takes place, as distinguished from shrinking or warping.
2. Softening temperature, when the cone fuses to a spherical lump.
3. Fluid temperature, when it spreads out in a thin layer.

Cochrane Corporation Fuels Section 1 page 66



Seger Cones after Use.



What constituents of coal are not combustible?

Ash, moisture, nitrogen

Kent's page 2-8

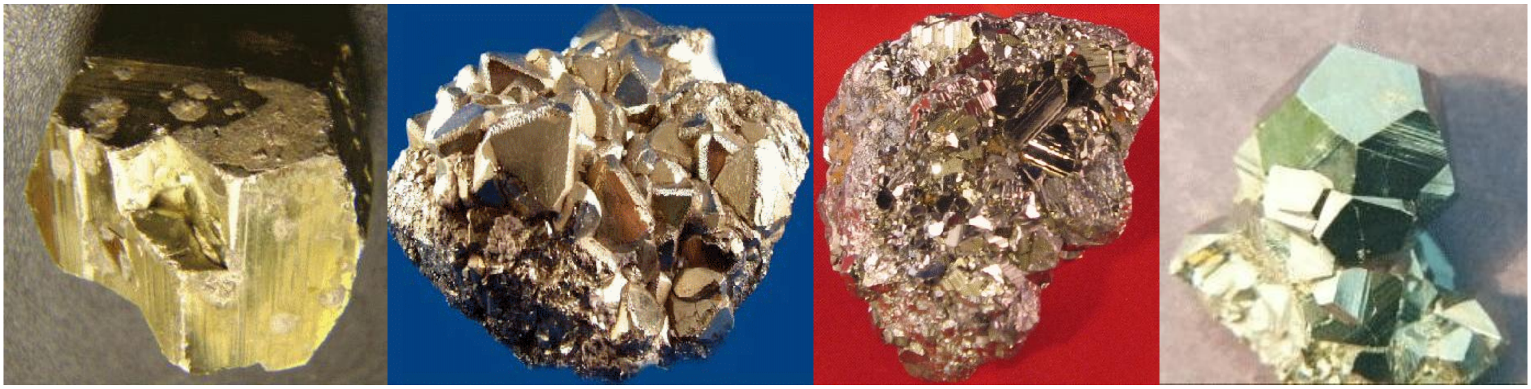
What are pyrites?

Pyrites are impurities found in coal, iron in nature. Large chunks of pyritic material, which can be as large as a foot of more in diameter, usually can be removed by cleaning the coal.

Power Feb. 1974 page S-7

Pyrite in coal

Pyrite in Coal



Pyrites

If the fusion temperature of the ash is low, what type of furnace bottom should be used and why?

There are two different methods of furnace design for low fusion ash coals.

At high firing rates ash which was deposited on the furnace bottom became sticky and fused into a sheet covering the entire hearth and removal was extremely difficult. This accumulation of slag, together with the erosion of sidewalls, caused many shutdowns. It became apparent that if the temperature of the ash deposit could be lowered below the plastic, or sticky temperature, it could then be removed in a dry or powdered form. To keep the furnace free of slag the water screen was developed. The screen consists of a series of tubes through which water is circulated, and is located above the furnace floor so as to provide a shielded and cooled zone in which the collected ash is maintained at a temperature lower than its fusion point.

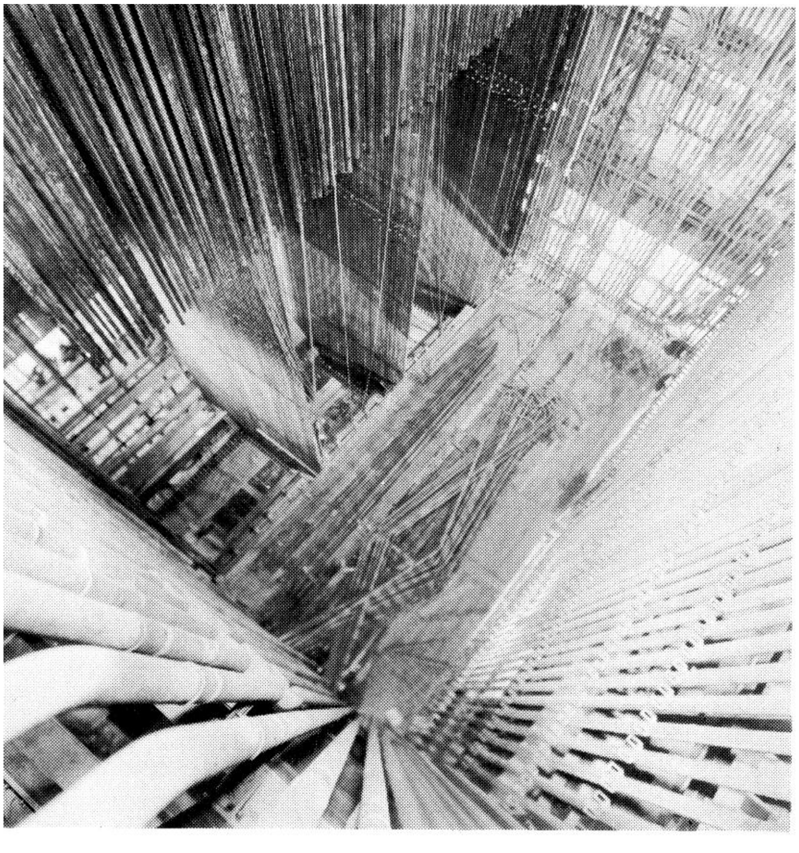
Blue Combustion Engineering page 9·34

A slag drip opening is located in the bottom of the furnace. A water-cooled ring, receiving its cooling water from a source outside the boiler, forms a slag dam and drip edge. Any excess accumulations continually drip through this opening, and are quenched in a suitable water-filled chamber. Slagging can be satisfactorily carried out over a wide load range when operating with low-fusion ash coals.

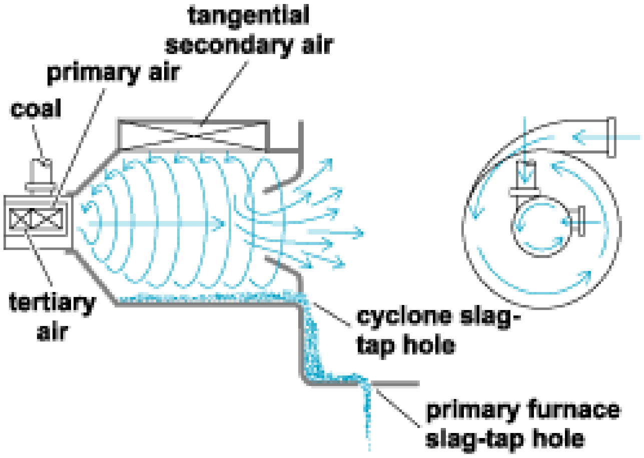
Blue Combustion Engineering page 9·48 and 9·49

The ash in coal presents a problem which must be given careful consideration in furnace design. In small and medium units ash is removed from the furnace in a dry state. In some large units, the ash in the furnace is maintained at a temperature higher than the melting point. The molten slag is tapped and allowed to flow in a liquid state from the bottom of the furnace into a trough of water where it is quickly chilled and shatters into small pieces.

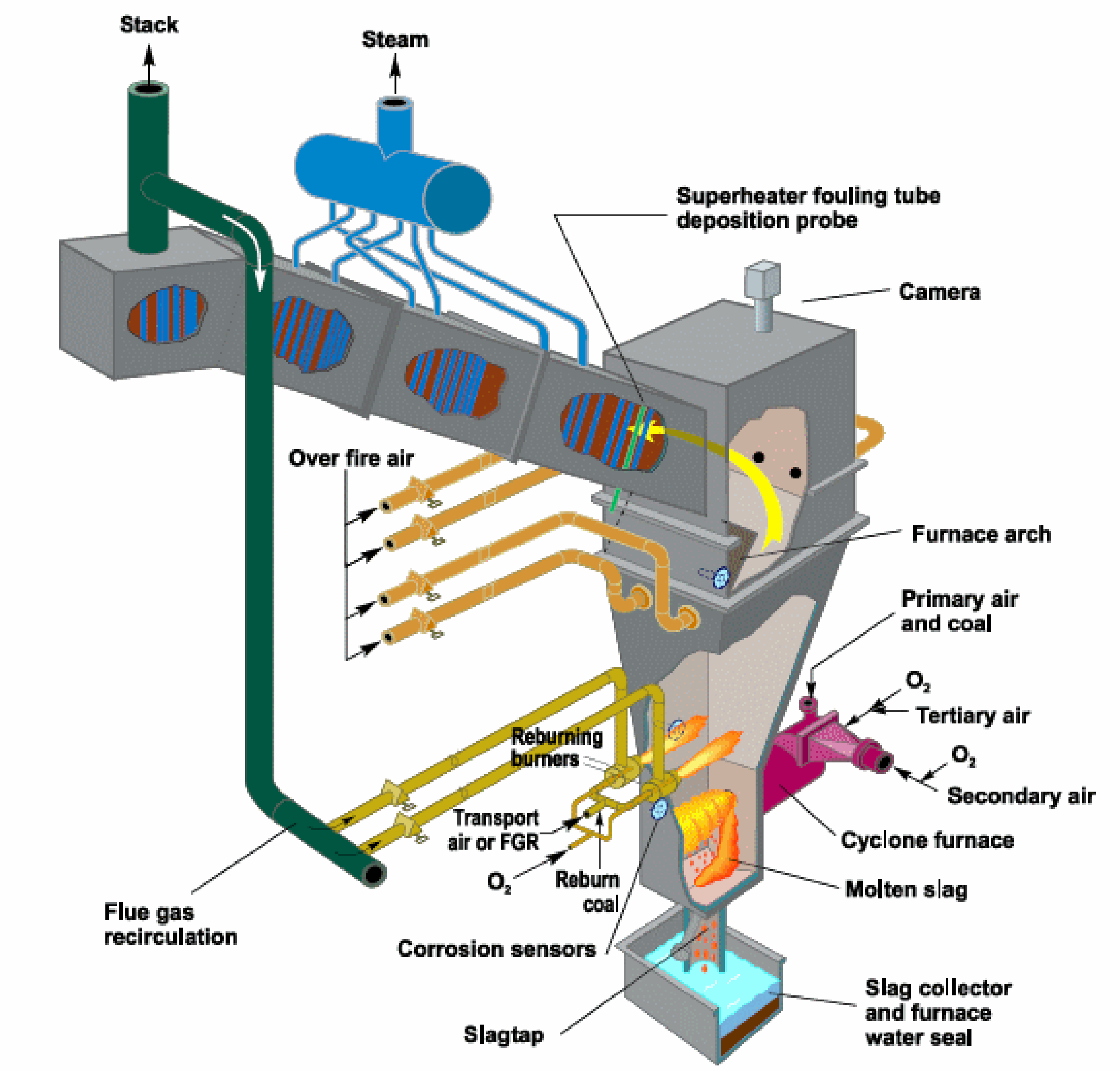
Steam Plant Operation by Woodruff and Lammers 4th edition page 188



Looking down at the bottom of the furnace under construction, you can see the water screen at the furnace floor. It is the diamond pattern tubes and the tubes alongside them. They cool the ash below the fusion point so that the ash can be removed in a dry state. The water for the water screen can be from the boiler supply or from a separate source. The tubes hanging down from the top are the pendant radiant superheaters. The waterwalls are the tubes surrounding the furnace.



The cyclone furnace burns coal in a large tubular chamber that keeps the ash in a molten state. Cyclone furnaces are not used much anymore because the high temperatures, (3500° F) produce excessive NOX



The molten ash pours out the slag tap hole into a tank of water where the molten ash shatters on contact.

What is the ignition temperature of various fuels and which coal can handle the highest fuel/air outlet temperature into the furnace?

The ignition temperature for a given substance is not a fixed temperature but depends upon a number of factors such as:
1. The surface exposed by the consumed surface
2. The pressure of the gas or vapor
3. The presence or absence of adjacent substances
4. The nature of the adjacent surfaces

Hence no definite ignition temperature can be given for a substance unless other factors are specified also. Ignition conditions are determined by several variables of which temperature is only one. For the usual conditions in boiler furnaces, ignition temperatures are approximately:

1. Bituminous Coal	766° Fahrenheit
2. Low volatile Bituminous Coal	870° Fahrenheit
3. Anthracite Coal	925° Fahrenheit

Practical Heat Croft page 440

Ignition temperatures in degrees Fahrenheit

Coke	1123-1300
Anthracite	1100-1300
Semi-Bituminous	870-982
Bituminous	800-975
Lignite	850-980
Pine wood	743
Mine Timbers	400-750
Cannel Coals	670-700
Soft Charcoal	650
Sulfur	470
Dry Peat	440
Methane	1382
Carbon Monoxide	1262
Hydrogen	1092
Ethylene	1017
Ethane	1000
Acetylene	824

Therefore anthracite can handle the highest outlet air temperature

Power Handbook on Fuels 1934 page 43

What is the most important element in determining dew point?

The sulfur content of the coal. The dew point of the flue gas is difficult to determine if sulfur is present in the fuel. With no sulfur present, it would normally be about 120 degrees Fahrenheit but with a small amount of SO_3 and water vapor both present, the dew point may be increased to more than 300 degrees Fahrenheit Consequently some external corrosion of the economizer may be expected when the entering temperature of the water is lower than the dew point of the gas.

Kent's 12th page 7-34

What are the sizes of bituminous coal and anthracite coal?

bituminous coal

1. Run-of-mine coal is shipped as it comes from the mine, without any screening.
2. Run-of-mine 8 inch coal is run of mine with oversize lumps broken up.
3. Lump is coal coming from the mine that will not pass through a 5-in. round-hole screen
4. Egg coal goes through a 5-in. round opening and is retained on a 2-in. round-hole screen.
5. Nut passes through a 2-in. round hole and is retained on a 1 1/4-in. round-hole screen.
6. Stoker coal is passed by a 1 1/4-in. round hole, but held on a 3/4-in. round-hole screen.
7. Slack coal, passes through a 3/4-in. round-hole screen.

anthracite coal

	Passing Through	Retained Upon
Broken	4& 3/8 in.	3& 1/4 by 3 in.
Egg	3& 1/4 by 3 in.	2& 7/16 in.
Stove	2& 7/16 in.	1& 5/8 in.
Chestnut	1& 5/8 in.	13/16 in.
Pea	13/16 in.	9/16 in.
No. 1 Buckwheat	9/16 in.	5/16 in.
No. 2 Buckwheat (rice)	5/16 in.	3/16 in.
No. 3 Buckwheat (barley)	3/16 in.	3/32 in
No. 4 Buckwheat	3 & 1/32 in.	3/64 in.

Culm or River coal is the still smaller from screening anthracite into prepared sizes. Today, it is often dredged from rivers into which it was dumped originally as unusable.

Power Feb. 1974. pages S-9 & S-10

Which coal causes difficulty in burning due to smoke and high sulfur content?

bituminous coal

When bituminous coal is in use and is not burned completely, smoke accompanies these flue gases. Initially the particles of tarry and sooty material are very fine, but they tend to coagulate, and the denser the smoke emission the greater the degree of coagulation.

Smoke, The problem of Coal and the Atmosphere 1948 by Marsh page 37
Steam Plant Operation by Woodruff and Lammers 5th edition, page 111

What is meant by free burning coals?

In free burning coals, the individual pieces do not fuse together but burn separately. If fusion does take place, the mass quickly breaks into fragments which burn separately. While burning, the air flows in irregular passages between the pieces of coal and the combustion is nearly uniform throughout the fuel bed.

Detroit Edison Steam Course Fuels and Combustion page 2 Question 11

List the coals from the highest volatile matter to the least volatile matter?

Lignite North Dakota	41.8%
Lignite Texas	44.1%
Subbituminous C Wyoming	42.8%
Subbituminous B Wyoming	42.8%
Subbituminous A Wyoming	38.9%
Bituminous high volatile C Illinois	36.4%
Bituminous high volatile B Colorado	39.2%
Bituminous high volatile A Pennsylvania	34.3%
Bituminous med. volatile West Virginia	22.2%
Bituminous low volatile West Virginia	16.0%
Semi-Anthracite Arkansas	13.0%
Anthracite Pennsylvania	3.4%
Meta-Anthracite Rhode Island	2.8%

Coal data: a reference by Eugene R. Slatick page 108
Kent’s 2th pages 2-26 to 2-30

Which coal contains the highest % of O_2

Lignite North Dakota 20.7%

Blue Combustion Engineering page 1·6

What type of coal has the most internal moisture?

Lignite -- 40%.

Power Plant Engineering page 1. 159

Which coal requires finest pulverization, anthracite, lignite, or bituminous?

anthracite

The index is relative, since large values, such as 100, represent coals that are more easily pulverized than those having smaller values, such as 40, which are difficult to pulverize.

Steam Plant Operation by Woodruff & Lammers 8th edition page 212

Grindability indexes of United States coals range from about 20 for an anthracite to 120 for a low-volatile bituminous coal.

Marks Standard Handbook for Mechanical Engineers by Eugene A. Avallone, Theodore Baumeister, Ali Sadegh, Lionel Simeon Marks copyright 2006 page 215

Of these three materials, which is released first in the combustion of bituminous coal; water, volatile matter, or carbon?

Moisture and volatile matter are first to be distilled off when fresh coal is charged into a hot furnace. The combustible matter in the volatile matter, along with the carbon monoxide and hydrogen formed by reactions of hot carbon with carbon dioxide and water, burns in the free space above the fuel bed which in the final analysis consists chiefly of carbon. **It should be noted that the first thing determined when conducting a proximate analysis is the moisture content.**

Blue Combustion Engineering page 2·24

What is the weight of a cubic foot of average compacted coal?

The average is 50 pounds per cubic foot. The U.S. Bureau of Mines Technical Paper 184 shows a range of weights of bituminous coals from 44 pounds per cubic foot to 59 pounds per cubic foot. This variance is due to size, moisture content, and locale.

Kent’s 12th 2-32 Table 6

The space occupied by anthracite varies with the size of the coal. Anthracite coal can weigh from 50.5 to 58 lbs. per cu. ft. Space occupied by bituminous coal varies with specific gravity of the coal, proportions of lump and slack, moisture content, and degree of settling. Bituminous coal can weigh from 43 to 59 lbs. per cu. ft.
Kent's p. 2-32

Broken anthracite, loose 52-56 lbs. per cu. ft.
Broken bituminous, loose 47-52 lbs. per cu. ft.

Combustion Engineering appendix page C·10 Table C·8

How much does a cubic foot of crushed coal weigh?

45 to 57 pounds per cubic foot

Kent’s 12th page 2-32

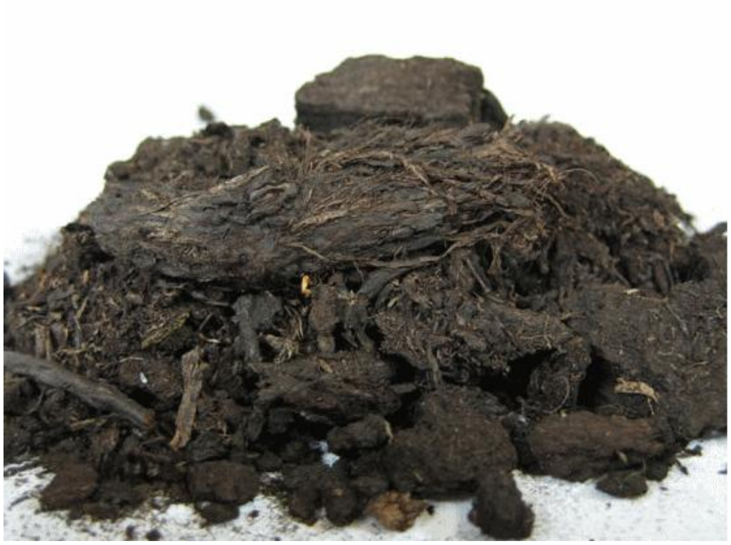
What is the correct tempering percentage of coal?

Tempering is the adding of water to coal. Improvements in operation can be obtained by tempering when the coal supply is dry, contains a high percentage of fine particles, or has a tendency to coke. Once coke has formed on the grates, the flow of air is restricted, making it very difficult to complete combustion and prevent an excessive amount of the coke from being carried over the end of the grate into the ashpit.

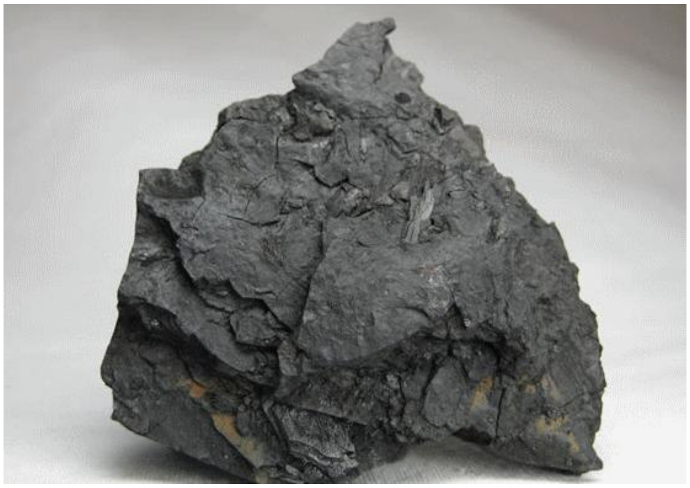
Steam Plant Operation by Woodruff and Lammers 6th edition page 154

Best results are obtained when the moisture content of the coal is 8 to 10%. The water should be added 10 to 24 hours before the coal is burned. The addition of water at the stoker hopper results in excessive amounts of surface moisture

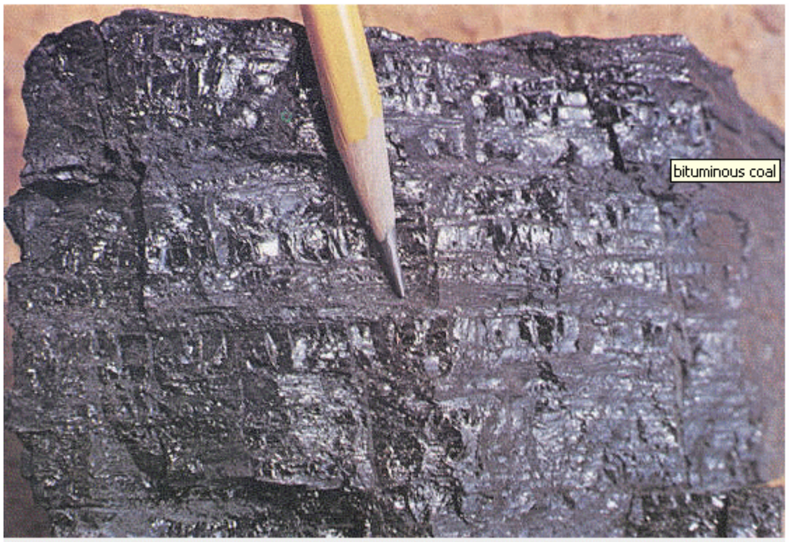
Steam Plant Operation by Woodruff and Lammers 8th edition page 255



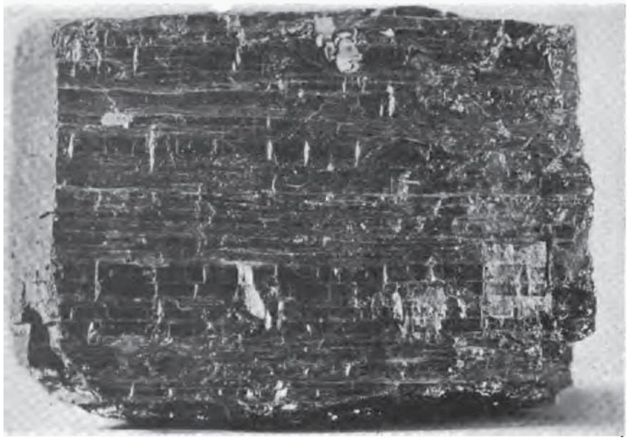
Peat



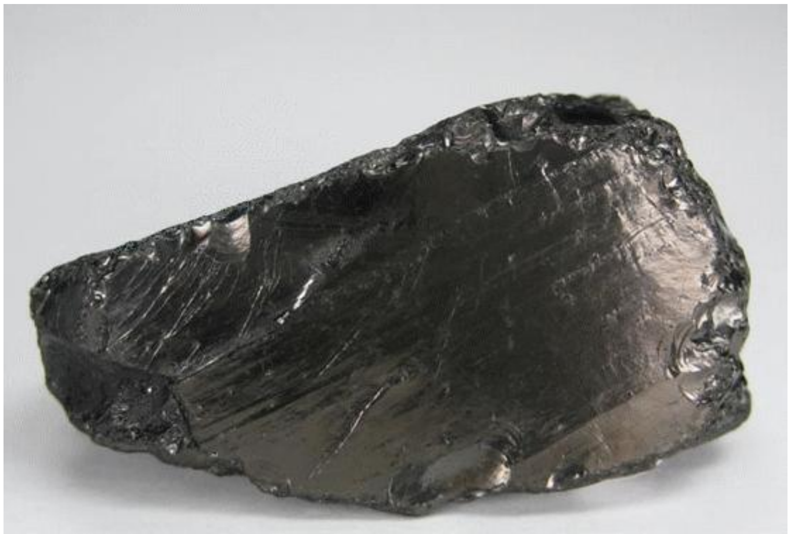
Lignite



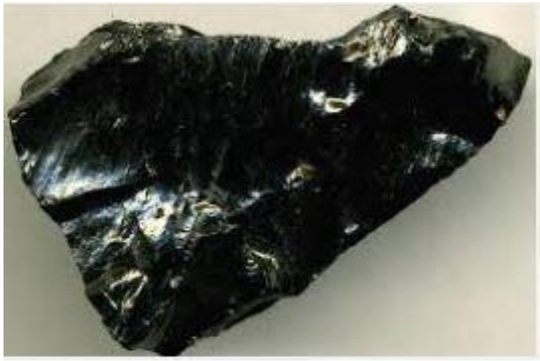
Bituminous Coal: Bituminous coal is typically a banded sedimentary rock. In this photo you can see bright and dull bands of coal material oriented horizontally across the specimen. The bright bands are well preserved woody material, such as branches or stems. The dull bands can contain: mineral material washed into the swamp by streams, charcoal produced by fires in the swamp, or degraded plant materials. This specimen is approximately three inches across.



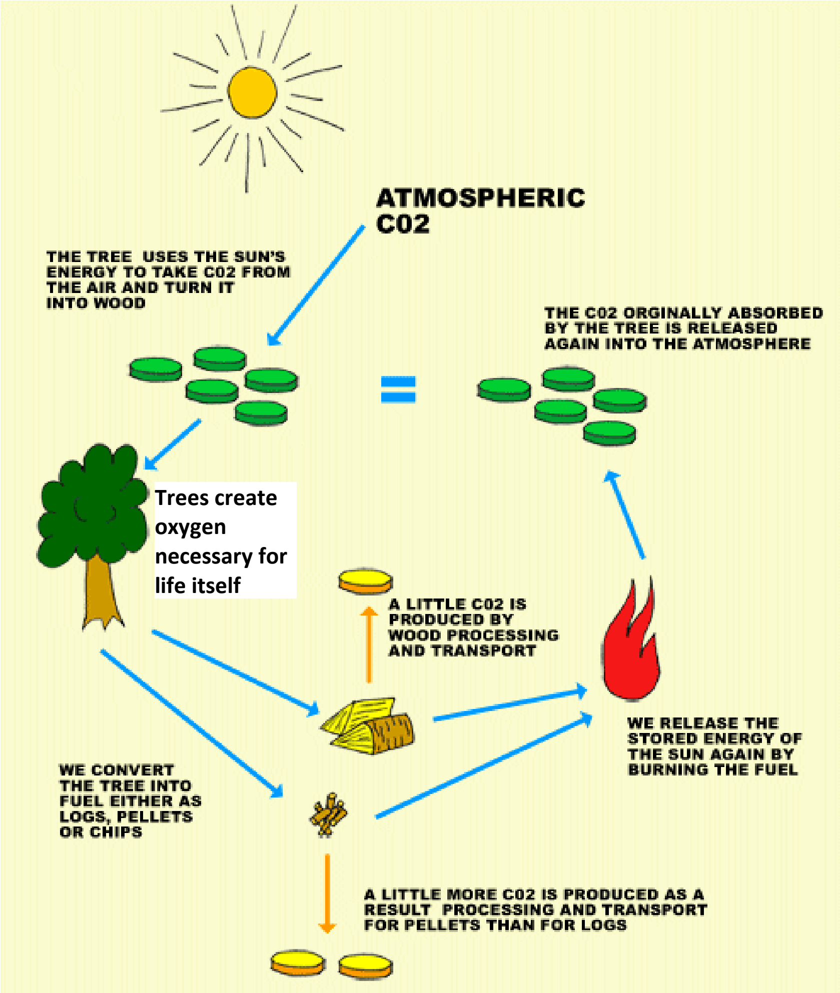
Bituminous Coal



Anthracite



Anthracite


ATMOSPHERIC C02
THE TREE USES THE SUN'S ENERGY TO TAKE C02 FROM THE AIR AND TURN IT INTO WOOD
THE C02 ORGINALLY ABSORBED BY THE TREE IS RELEASED AGAIN INTO THE ATMOSPHERE
Trees create oxygen necessary for life itself
A LITTLE C02 IS PRODUCED BY WOOD PROCESSING AND TRANSPORT
WE RELEASE THE STORED ENERGY OF THE SUN AGAIN BY BURNING THE FUEL
WE CONVERT THE TREE INTO FUEL EITHER AS LOGS, PELLETS OR CHIPS
A LITTLE MORE C02 IS PRODUCED AS A RESULT PROCESSING AND TRANSPORT FOR PELLETS THAN FOR LOGS

The best CO2 reclamation plants are the plants themselves.

A Montana coal having a heating value of 10,400 BTU's per pound, with 14% moisture and 6.5% ash will have what heating value on a dry and combustible basis?

Dry basis = heating value/1 - moisture
Dry = 10,400 BTU/lb/1 - .14
Dry = 10,400 BTU/lb/ .86
Dry = 12,093.023 BTU/lb

Combustible basis = heating value/1 - (moisture & ash)
Combustible = 10,400 BTU/lb/1 - (.14 + .065)
Combustible = 10,400 BTU/lb/.795
Combustible = 13,081.761 BTU/lb

Coal on and as received basis has 14,600 BTU's/lb, with 7% ash and 20% moisture. Find the BTU value on a moisture free and also on an ash free basis.

Dry basis = heating value/1 - moisture
Dry= 14,600 BTU/lb1 - .20
Dry= 14,600 BTU/lb/ .80
Dry= 18,250 BTU/lb

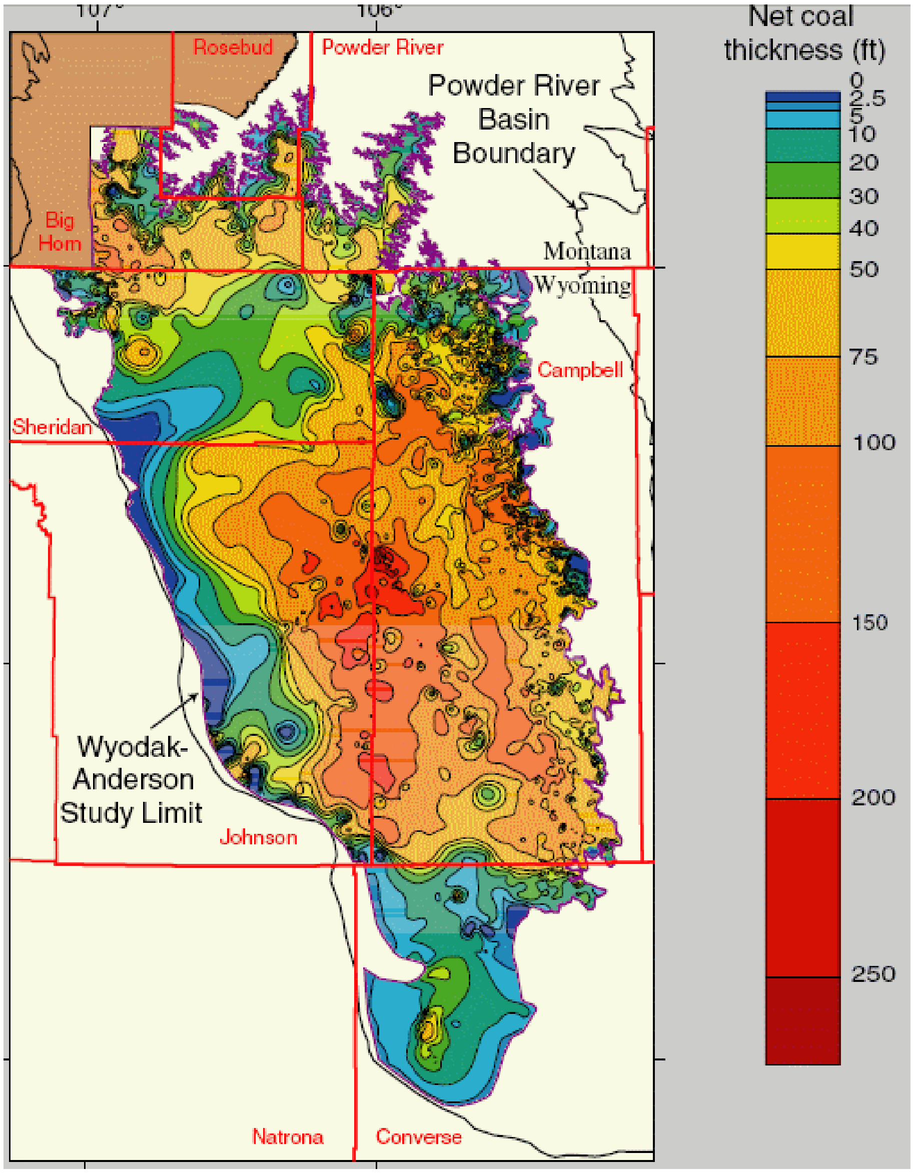
Combustible basis = heating value/1 - (moisture & ash)
Combustible = 14,600 BTU/lb/1 - (.20 + .07)
Combustible = 14,600 BTU/lb/.73
Combustible = 20,000 BTU/lb

Chapter 3 Coal Mining and Coal Handling

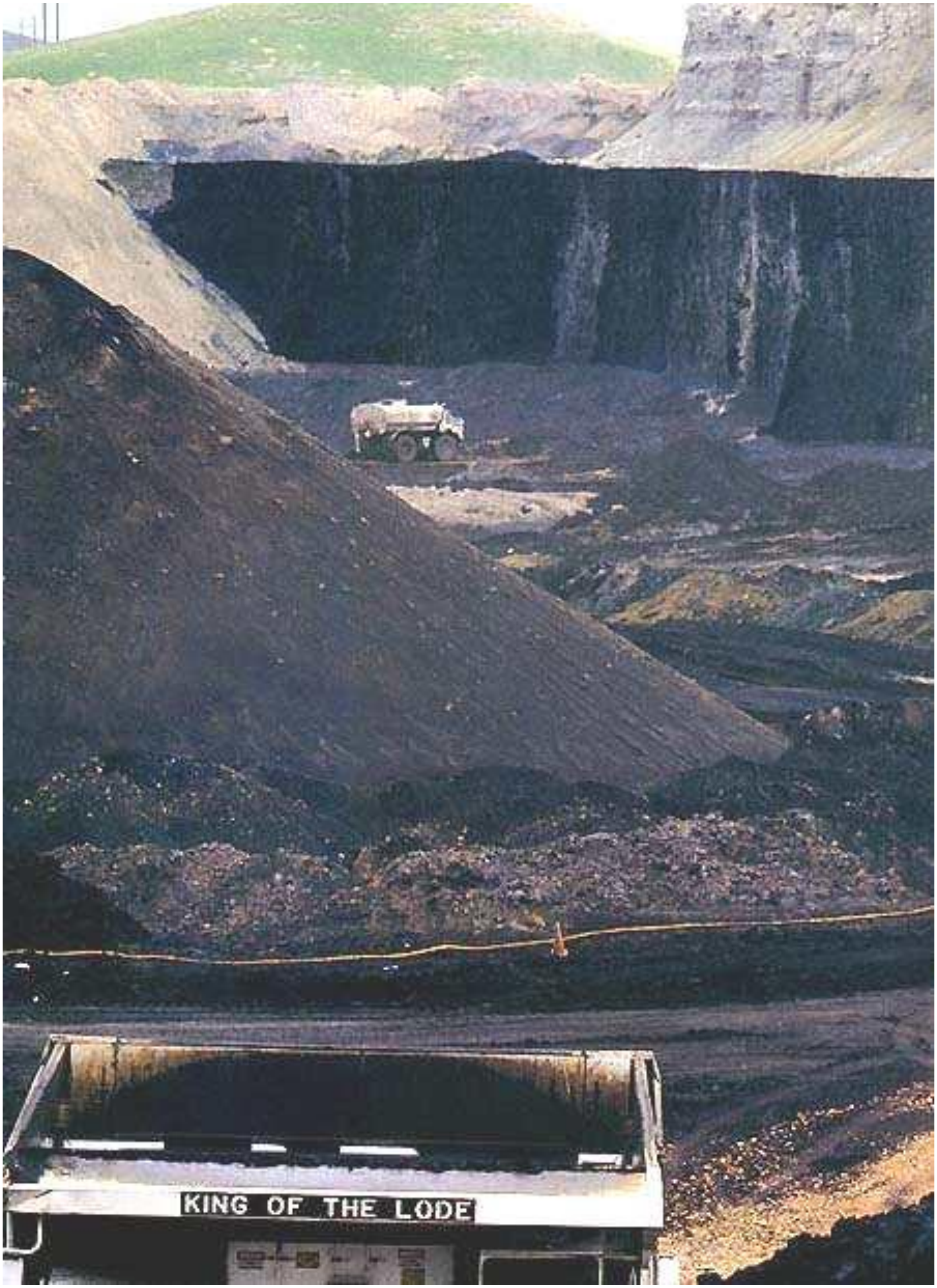
Describe in detail how Powder River Basin Coal is mined and delivered to Detroit Edison Plants

The Powder River Basin is the largest coal mining region in the United States encompassing parts of Wyoming and Montana. The Powder River Basin coal beds are shaped like elongated bowls and as mines expand from east to west in the Powder River Basin, they will be going "down the sides of the bowl." This means that removing the overburden (rock lying over the coal) will increase the expense to get to a ton of coal.

The current price is $10.47/ton.



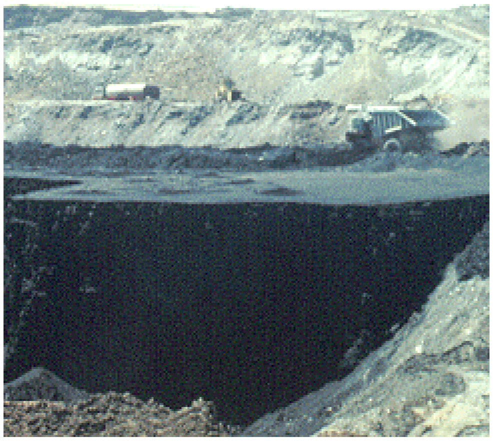
Powder River Basin Coal Geographic Area



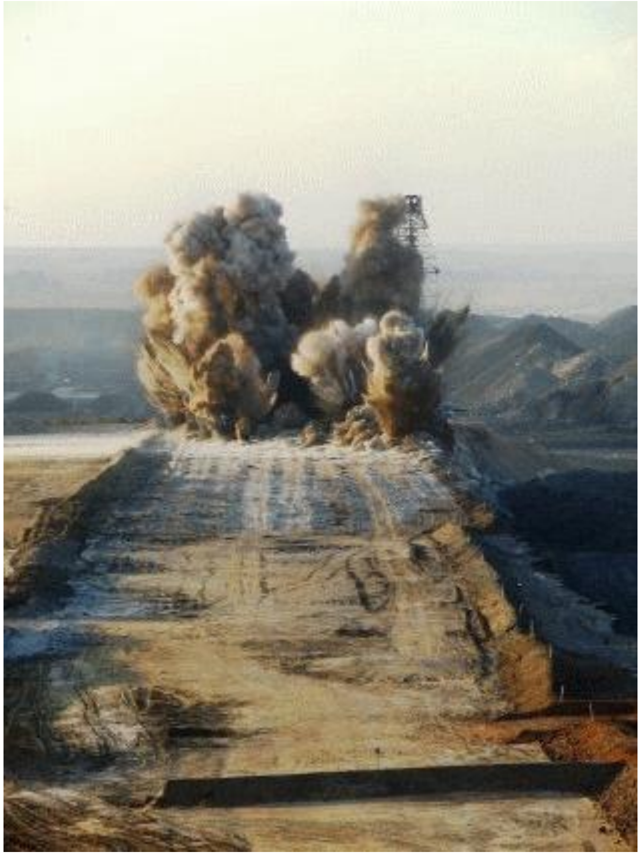
Powder River Basin coal seam

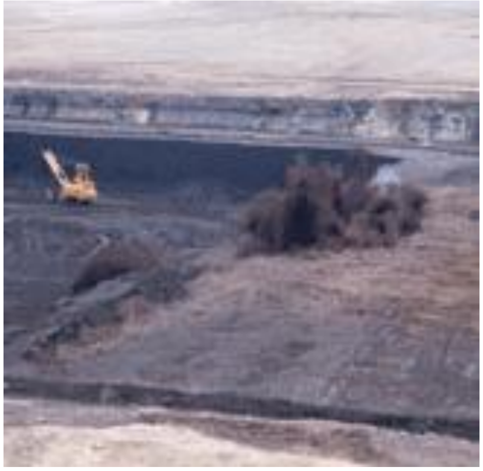
Powder River Basin Antelope Coal Mine

Powder River Basin coal is readily available. Powder River Basin coal is significantly lower in cost compared to coal from other primary coal producing regions, including the bituminous coals found in the Illinois Basin and Appalachia. Powder River Basin coal has a large amount of easily accessible reserves compared to Illinois Basin and Appalachian coals.

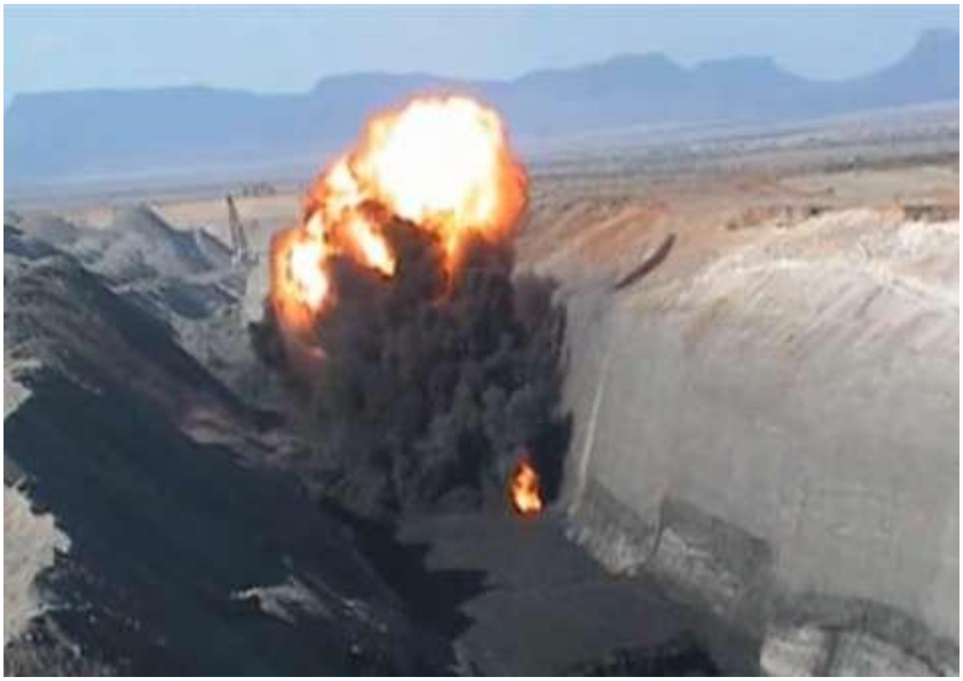


Showing the depth of coal at the Powder River Basin





The picture on the left shows blasting to remove the overburden. The picture above shows blasting of the coal seam to make it easier to load onto the trucks.



Blasting can result in a huge fireball as the coal dust ignites. Normally the fire goes out after the blast; as you will see in later pictures, sometimes not.

Presently there are approximately 15 mines in the Powder River Basin. They blast away the overburden and remove it with large electrically powered draglines and diesel and electric mining trucks.

From 50 to 245 feet of overlying rock has to be stripped away. Topsoil is stored for use during restoration. Black Thunder relies heavily on cast blasting to move between 20 and 30% of the overburden to its final position directly. The remainder is handled by the draglines. The coal is also blasted before loading.

Powder River Basin Coal Seam

The United States uses about 1 billion tons of coal a year, with about 40 percent of the coal currently coming from the Powder River Basin.

One of the largest mines is the Black Thunder Mine 50 miles south of Gillette, Wyoming. The coal seam is around 70 feet thick. The recoverable reserves of this one mine is 750 million tons and the current annual production capacity is 70 million tons.

COAL QUALITY

Powder River Basin coal is a low-sulphur, sub-bituminous coal suitable for power station fuel without any preparation except crushing. It has a heating of value approximately 8,500 BTU/lb and the ash contents are around 5% while as-received moisture is 25–30%. The moisture content of some Powder River Basin coals increases their reactivity to the extent that spontaneous combustion can be a problem if they are not properly handled. Contrast this with Eastern Appalachian bituminous coal containing an average of 12,500 BTU/lb and high SO_2. A coal-fired plant designed to burn Appalachian coal must be modified to burn PRB coal.

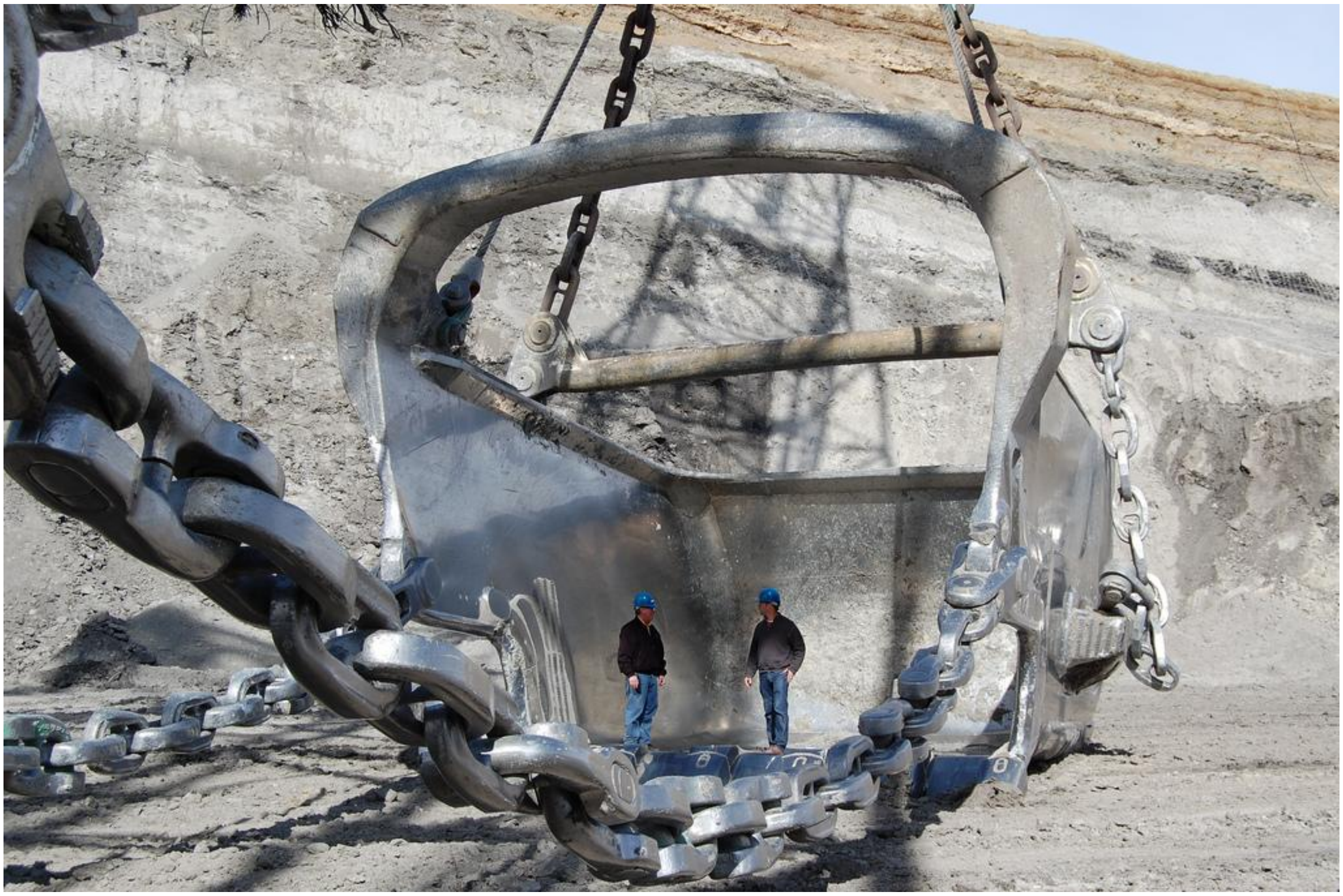
Coal Specifications:

Sub-bituminous coal………	8,800 Btu/lb
Sulphur……………………	0.32%
Moisture…………………..	27.0%
Ash………………………..	5.5%
Volatile Matter……………	29-35%
Fixed Carbon……………..	31.5-37.5%

Fusion Temperature of ash
Initial Deformation 2,100-2,170°F
Fluid 2,100-2,310°F

MINING EQUIPMENT

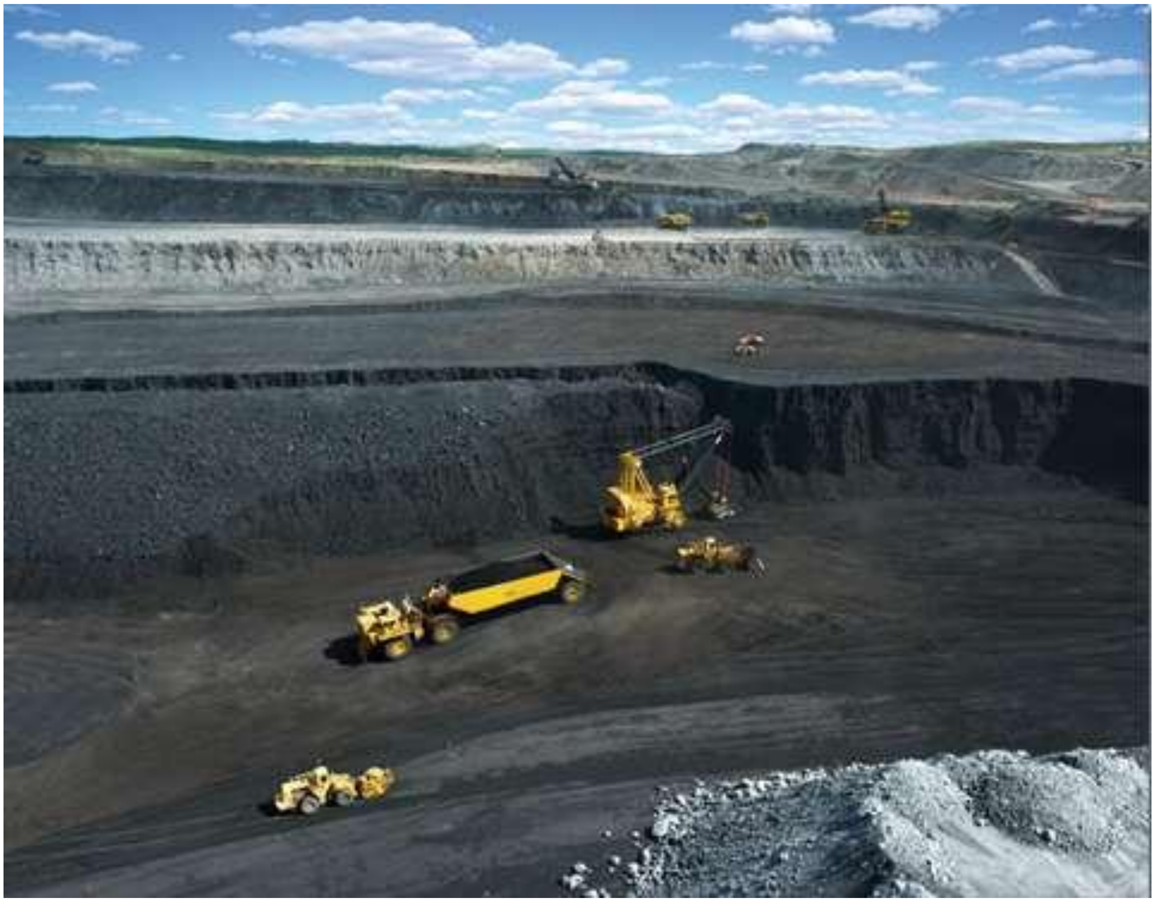
Black Thunder operates several individual open pits, using five large draglines for overburden handling. The dragline fleet includes Ursa Major, the largest of the three, a Bucyrus-Erie (B-E) 2570WS model weighing some 6,700 tons. The third-largest dragline ever built, it was assembled on site over a three-year period at a cost of $50 million. Its 360 foot long boom carries a 4300 cubic foot bucket.



Note the size of the men inside the Ursa Major dragline bucket to get an idea of the scale of operations at the Black Thunder Mine.

Of the other draglines, Thor, a B-E 1570W, has a 320 foot long boom and a 2450 cubic foot bucket, while Walking Stick is a B-E 1300W with a 300 foot long boom and a 1200 cubic foot bucket. Originally built at Coal Creek, another Arch Coal property where production was halted in 2000, it was tramped across the prairie to Black Thunder late 1991.

Electric shovel and dump truck deep within the coal seam

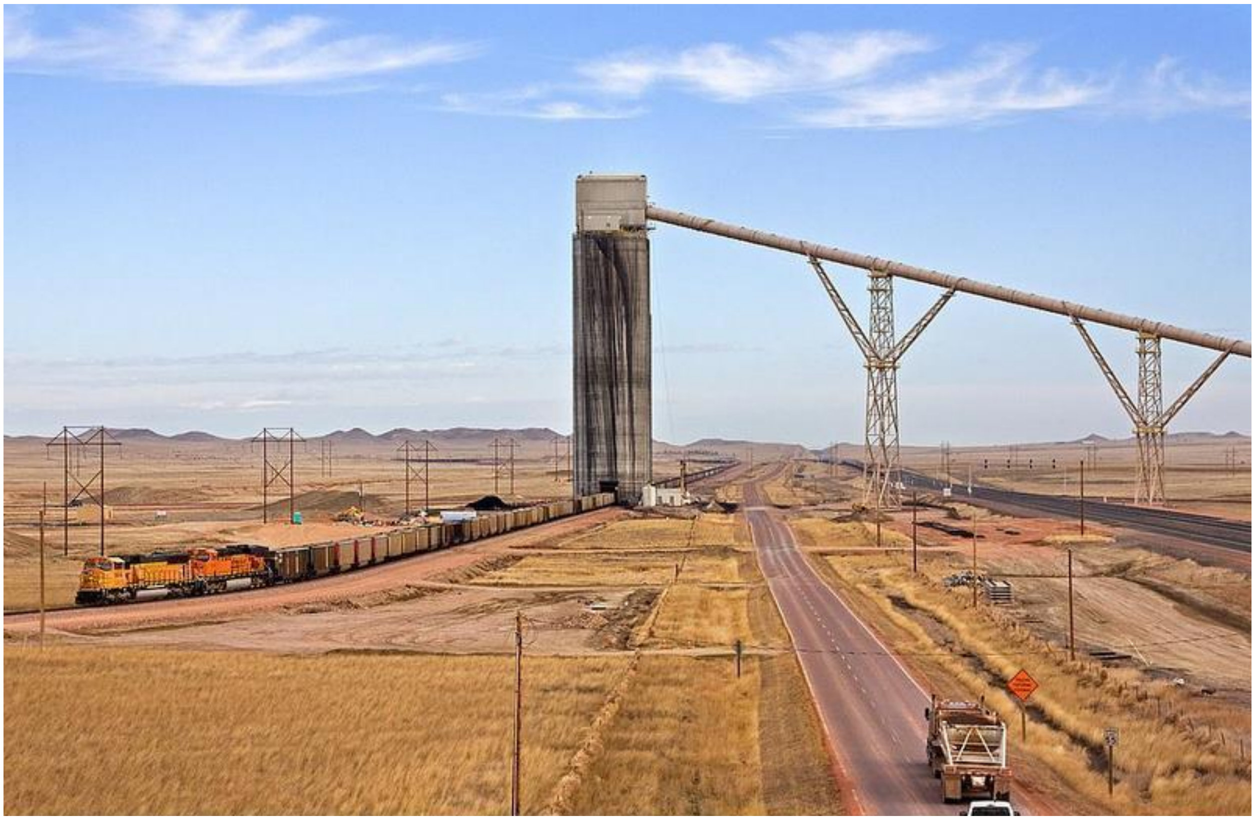


Note the blasted coal area and the coal seam where blasting has not yet occurred.

Loading goes on all day and night

The loaded truck dumps its coal into a hopper to be conveyed to the coal silos situated over the railroad tracks

Coal is hauled to a near-pit dump and crusher station, which feeds a 2 mile long overland conveyor to the coal storage and loadout silos.



Coal Loadout at Black Thunder Mine

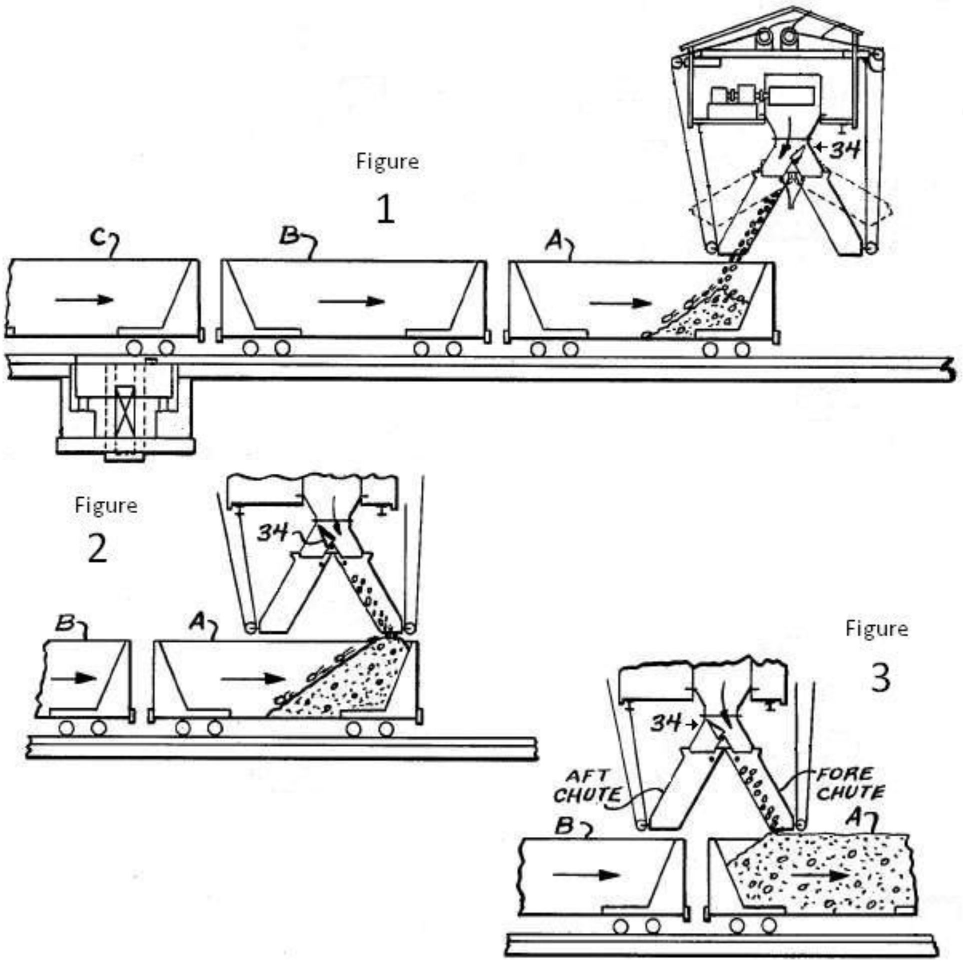
Some coal is cleaned, sorted and crushed to different sizes at preparation plants before loading for delivery, while other coal is shipped raw.

The coal is lifted by conveyor into two “loadout” silos that are located over the train rails.

Coal from the Black Thunder Mine is loaded into BNSF Railway and Union Pacific Railroad unit trains at the loadout. By having two railroads competing for business, shipping rates are lower than if only one railroad was available, known as a “captive haul”.

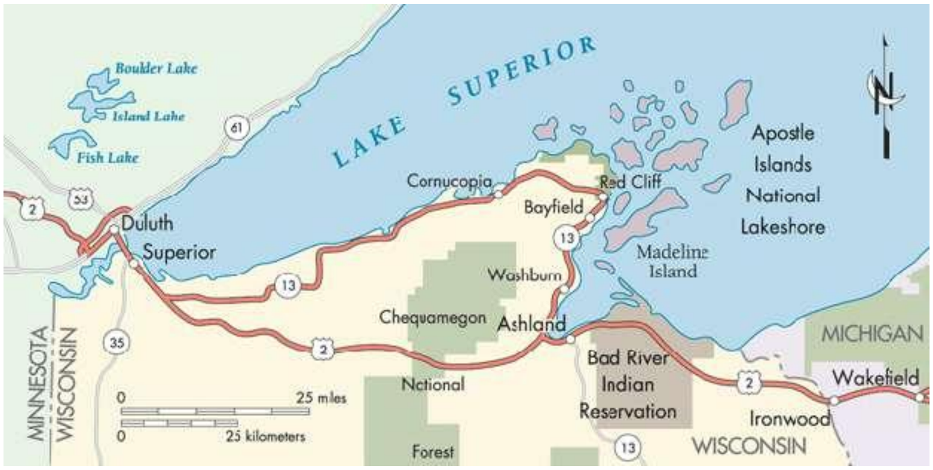
Rail Loading Point Storage Capacity is 126,000 tons. The Loadout Configuration consists of two high-speed unit train loadouts. Two silos and slot storage with the rail tracks running underneath the silo. They use three state-of-the-art batch loadout scale systems to assure maximum loading per car. The Ramsey weigh bin system drops premeasured batch quantities sized to car capacity loading 12,000 tons per hour. Two loop tracks and two loadouts can hold four unit trains on the track.

The coal is delivered Superior Wisconsin by unit trains. Each unit train would consist of between 120 and 135 rail cars with each rail car containing between 100 and 130 tons of coal.

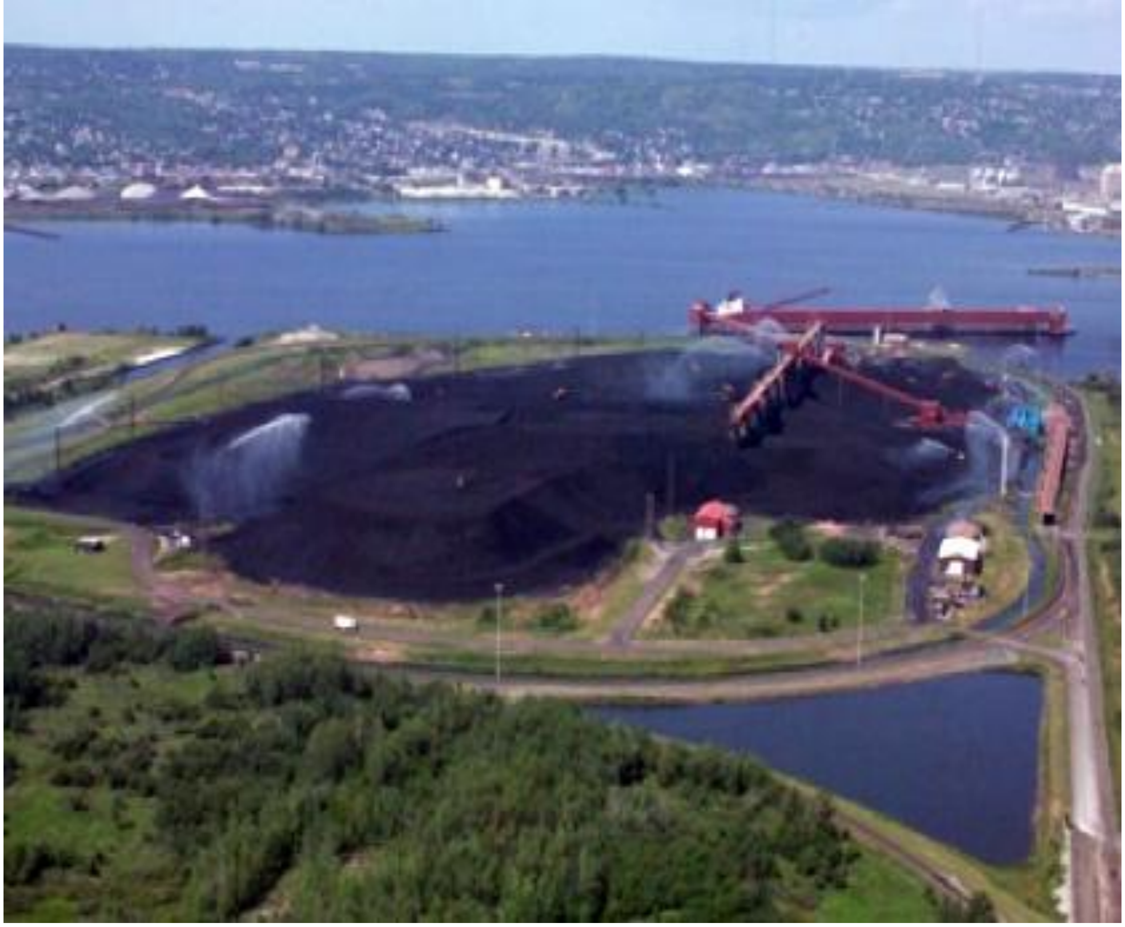


The Ramsey Weigh bin system has sensors that weigh the moving coal cars as they pass under the loadout hopper. In figure 1, valve 34 opens to allow the aft chute to start loading the car. In figure 2, as the car continues, valve 34 switches and the fore chute continues filling the car until it is full, as shown in figure 3. The process is continuous and the train never has to stop.

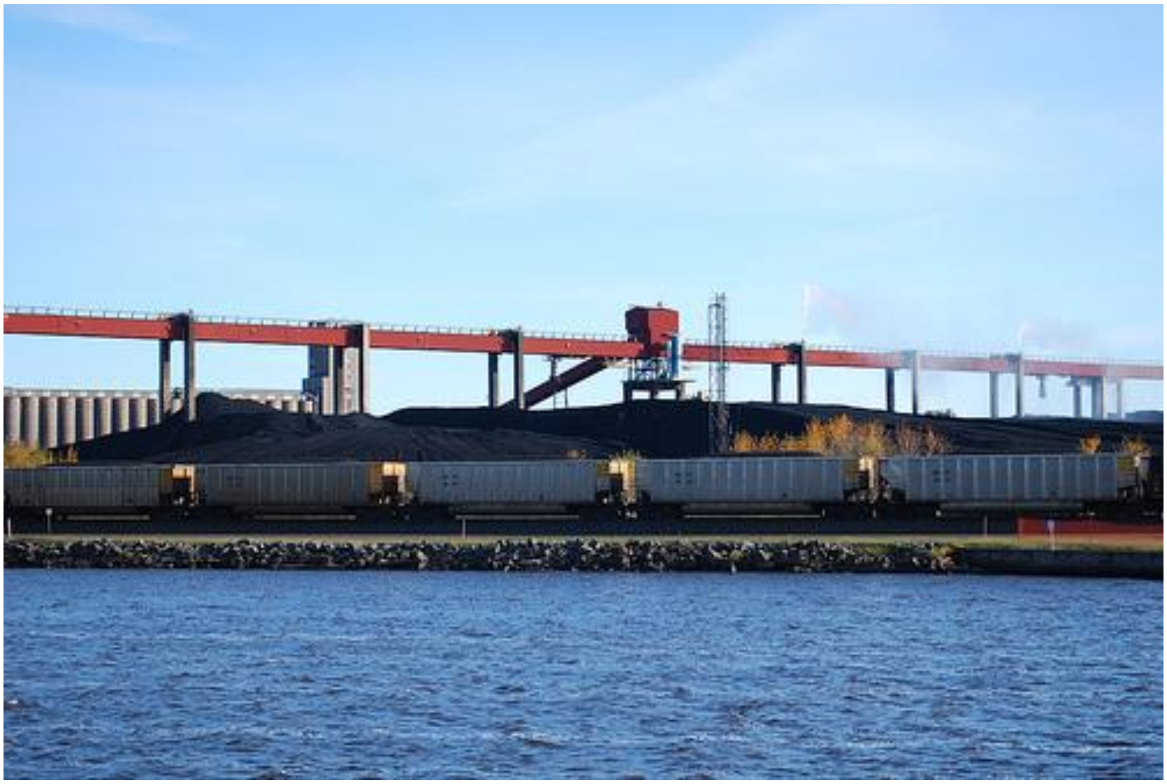
Powder River Basin Coal on its way to Superior Wisconsin. Due to the lower BTU value, special aluminum rail cars with higher sides are used to transport more tonnage of coal than Eastern coal. Note the uniformity of the coal from the loadout into each car due to the Ramsey Weigh Bin system.



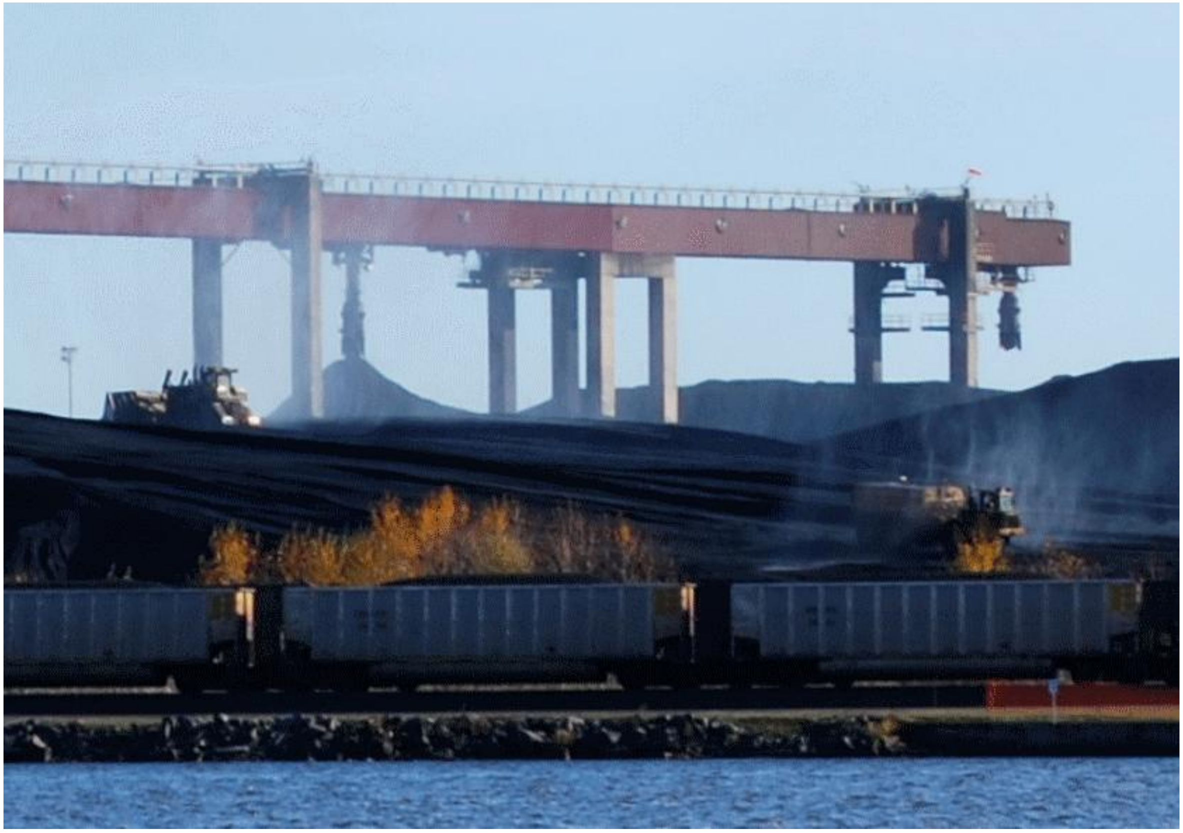
Superior Wisconsin is on the Western tip of Lake Superior and across the bay from Duluth Minnesota.



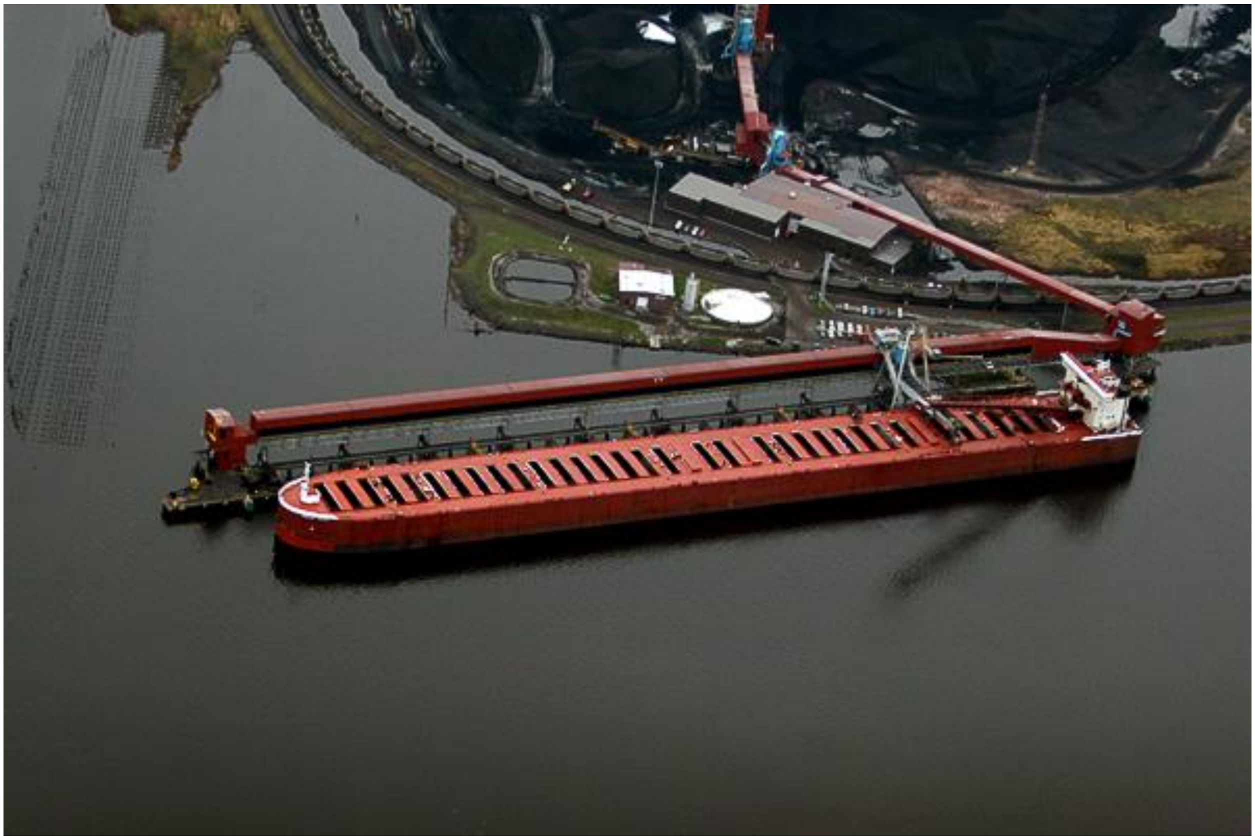
Train car unloading and Great Lakes Freighter loading facility at Superior Wisconsin. Notice the brown sheds on the right where the coal cars are unloaded. The coal travels underneath to the crusher house and then up the angled conveyor to the horizontal conveyor to be loaded onto the ship or dropped onto the coal pile. The water cannons are to suppress the dust although it creates problems with spontaneous combustion. Note how the rail tracks encircle the coal pile. Bulldozers are on the pile smoothing and packing it. The facility is located on St. Louis Bay at the mouth of the St. Louis River. The Burlington Northern Santa Fe and the Union Pacific Railroads both unload coal at this facility. The facility is run by the Midwest Energy Resources Company.



The trains arrive at the Midwest Energy Resources Company terminal at Superior Wisconsin. The facility operates 24 hours a day 7 days a week. Midwest Energy Resources is a subsidiary of DTE Energy. It has a ground storage of 5 million tons. They can handle 25 million tons of coal a year from this facility.



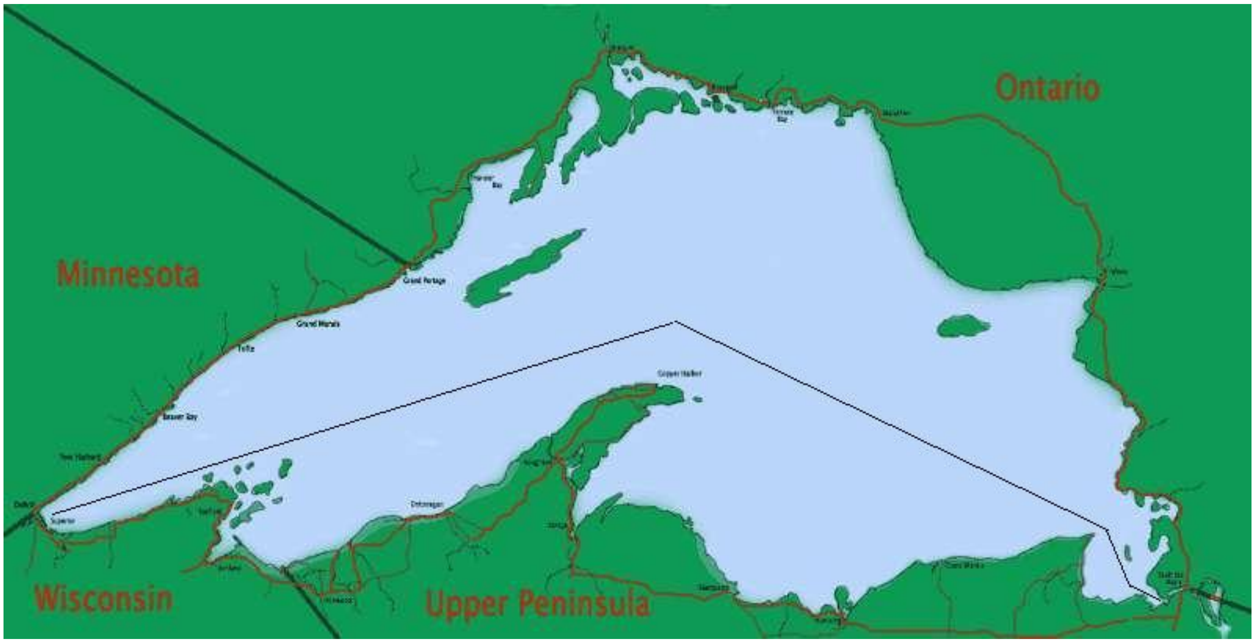
This close-up shows the bulldozers compacting the coal in layers to suppress dust and help prevent spontaneous combustion. Note the two cylindrical coal chutes that drop coal closer to the pile to try and minimize dust.



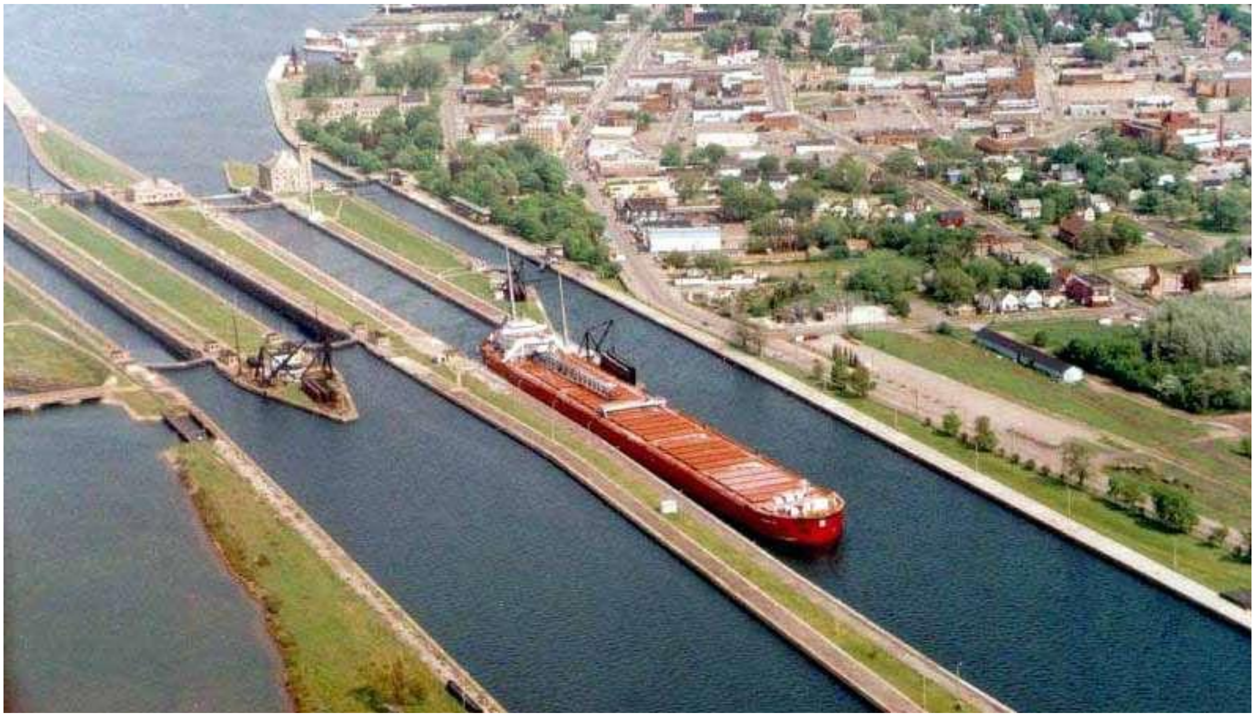
Coal is loaded onto a waiting Great Lakes Freighter at the Midwest Energy Resources Dock

Filling one of the separate coal bunkers on the Great Lakes freighter at the Midwest Energy Resources dock. The dock is 1200 feet long and can handle ships up to 1105 feet long and 105 feet wide.

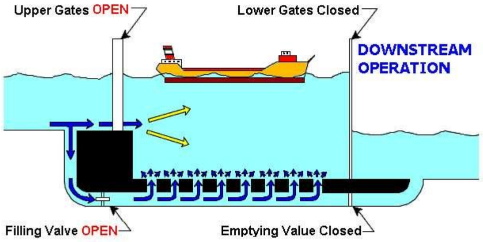
The loaded freighter travels across Lake Superior to Sault Ste Marie and through the Soo Locks.

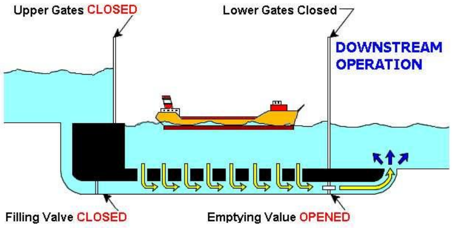


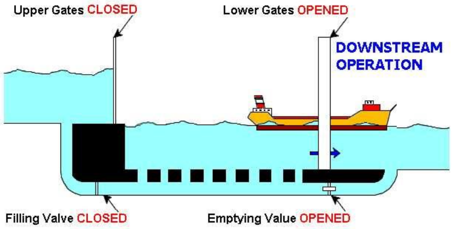
From the far Western tip of Lake Superior, the freighters travel across the lake to the Soo Locks on the far Eastern tip where the lake connects to the St. Mary's River.



The Poe lock is 1350 feet long and 110 feet wide. Great Lakes Freighters are limited in size when being built to the size of the largest Soo lock. A new "Super Lock" is now under construction. The two smaller locks will be consolidated into the one new lock. The freighters spend their life on the Great Lakes as they are too large to go through the St. Lawrence Seaway to the Atlantic Ocean. The new Super Lock should lead to even larger freighters.

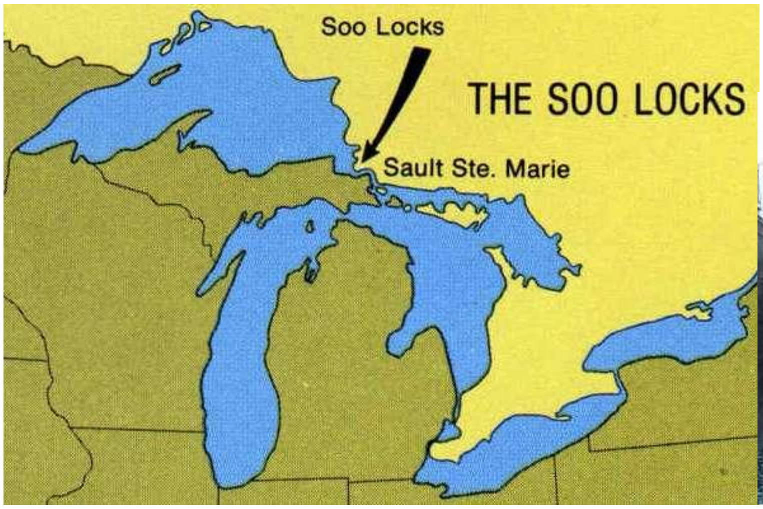






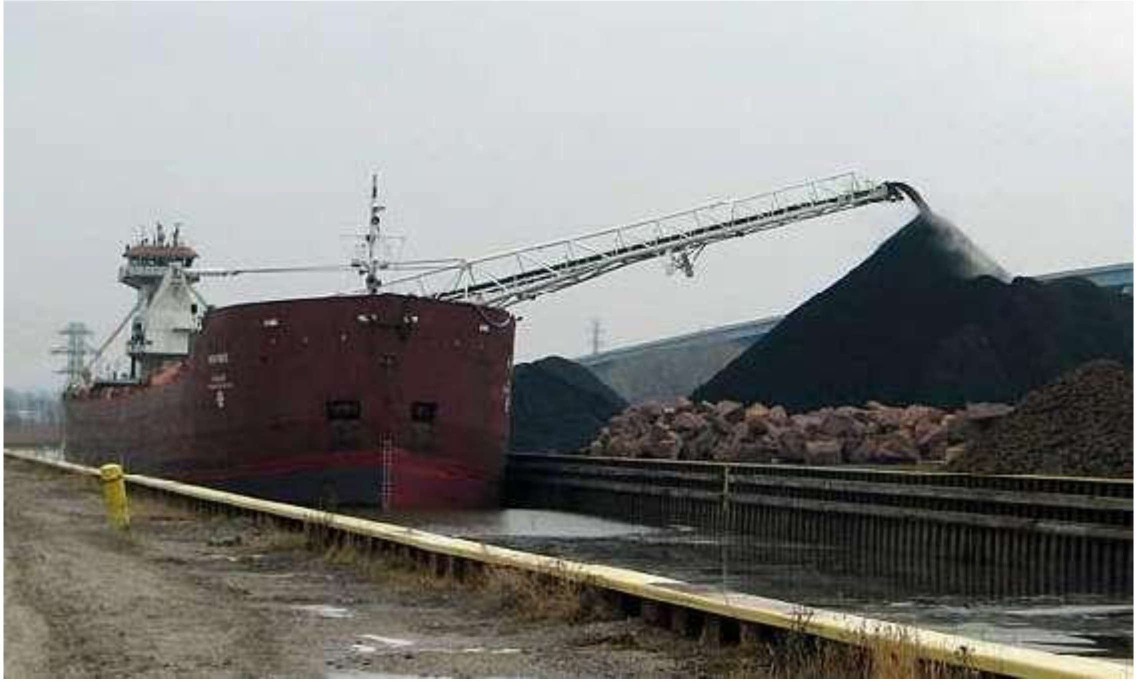
The diagram above shows how the freighter enters the lock from Lake Superior, and is lowered the 25 feet from the height of Lake Superior to height of Lake Huron and the other Great Lakes. By operating gates and valves, vessels can make the journey from Superior Wisconsin to the power plants of Detroit Edison.

The largest vessels on the lake are the 1000 footers. These vessels are between 1000 and 1013.5 feet long, 105 feet wide and of 56 feet hull depth. They can carry as much 88,312 tons of bulk cargo although their loading is dependent on lake water levels especially in the channels and ports. A dozen of these giant ships were built, all constructed between 1976 and 1981, and all are still in service today.

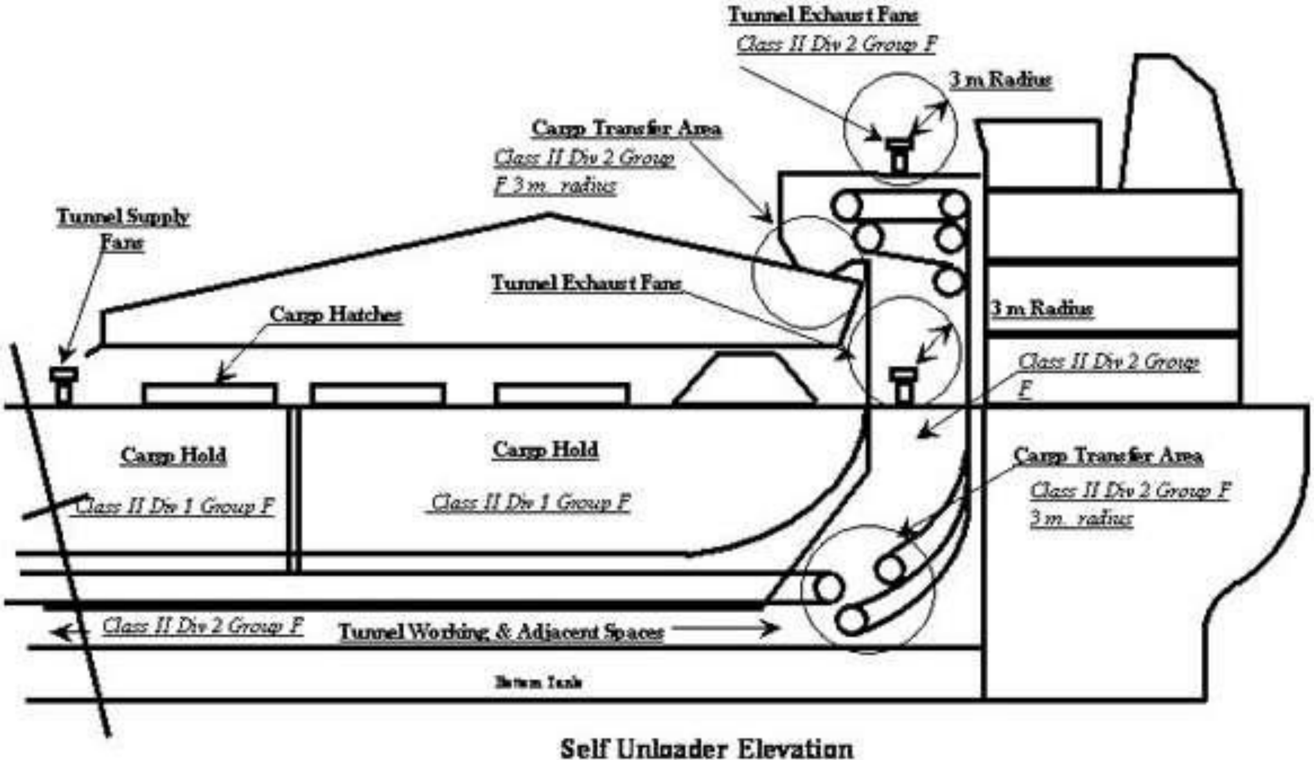


After the freighter goes through the Soo locks it enters the six bodies of water on the East side of Michigan, namely the St. Mary's River, Lake Huron, the St. Clair River, Lake St. Clair, the Detroit River and Lake Erie. Detroit Edison's service area covers most of the Eastern "thumb" of Michigan.

The lock is closing to allow water from Lake Superior to fill the lock and raise the water level 25 feet to allow the freighter to enter. After the freighter is inside, the water will be drained out until the Freighter is at the level of Lake Huron and the freighter can proceed after the Lock doors are opened.



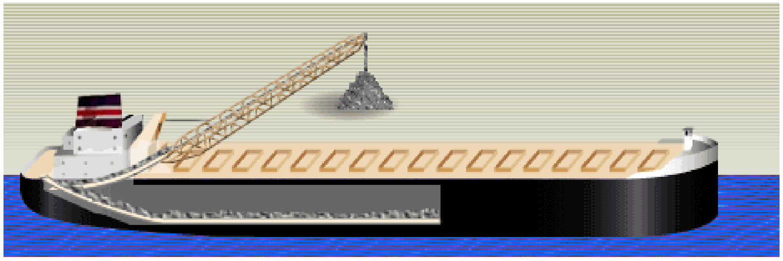
The freighter sails down Lake Huron to the Detroit Edison powerplants along the Detroit River and Lake Erie. The freighter has a self-unloading system consisting of an underbunker conveyor system that offloads the coal through a conveyor belt that swings toward shore and drops the coal in a conical pile. The individual bunkers are unloaded in a sequence that does not unbalance the ship.



Self Unloader Elevation

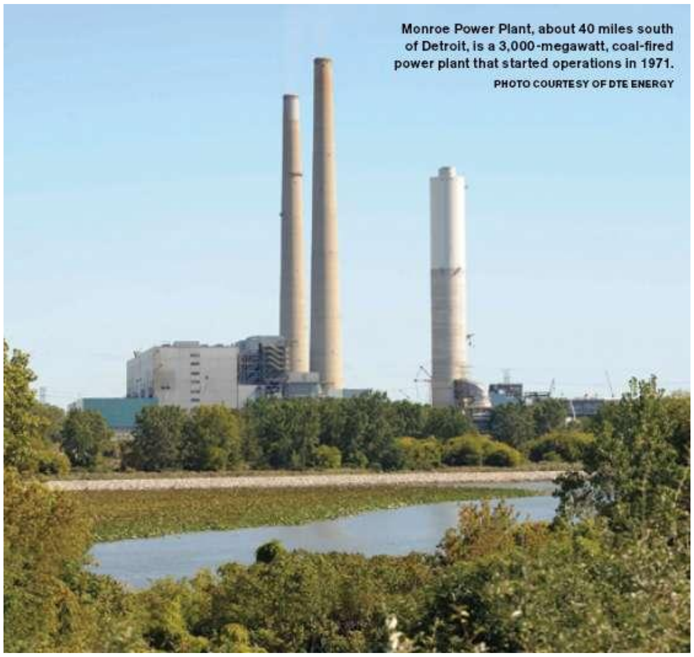
The coal is transferred from the Cargo Hold to the underbunker conveyor, to the Cargo Transfer Area which lifts it up to the swingout boom that has the transfer conveyor on it to offload the coal onto the shore.

The freighter uses its self-unloader to deliver the coal from its starting point at the Powder River Basin to the St. Clair and Monroe Power Plants



These self-unloading freighters have eliminated a lot of the manpower and equipment needed to unload the freighters. The ships have bow thrusters that allow them to maneuver in tight spaces without the aid of tugboats. To see a 1000 foot ship turn on a dime and head back upriver after unloading is an amazing sight. The Monroe Power Plant and the St. Clair Power Plant both use Powder River Basin coal.

St. Clair Power Plant



Monroe Power Plant, about 40 miles south of Detroit, is a 3,000-megawatt, coal-fired power plant that started operations in 1971.

PHOTO COURTESY OF DTE ENERGY

Monroe Power Plant

Monroe Powerplant Tour

Notes on Monroe Power Plant Coal Handling Facility

1. At Monroe they blend four different types of coal
   A. 3% Pennsylvania Mid-Sulfur 12,000-13,000 BTU/lb. $32 ton
   B. Low Sulfur Eastern coal
   C. Low Sulfur Southern coal
   D. Low Sulfur Montana coal $12-$18 per ton
   They blend the coal to try and maintain 1% sulfur

2. In order to control the flyash emissions they inject SO3, to increase the conductivity of the ash so that it will cling to the electrostatic precipitators better.

3. The yellow plume that can be seen coming from the stacks is the Nitrous Oxides that react with the sunlight and become visible

4. To combat the NOX they add tertiary air over the flame

5. They use #2 fuel oil for ignition

6. Detroit Edison sells the dry flyash from some of their plants (not Monroe) for binding agents with asphalt and when mixed with 5% Portland Cement for surrounding buried pipes for cathodic protection

7. Monroe supplies from 33% to 50% of the load for Detroit Edison. They used to be a base-loaded plant but now they have to drop output because of the decline in the manufacturing facilities in Southeast Michigan

8. They lowered the steam outlet temperature from 1050 to 1000 degrees F. to increase the life of the tubes.

9. The plant consists of 4 unit systems, each boiler dedicated to its associated turbine.

Staff
- 1 Shift Supervisor over entire plant
- (2) Assistant Shift Supervisors
  - 1 over #1 and #2 boiler, and #1 and #2 turbine
  - 1 over #3 and #4 boiler, and #3 and #4 turbine
- 1 Supervising Operator over each boiler and turbine set or 4 total

Each Supervising Operator has assistant Power Plant Operators under him, none of which need a license

10. The water temperature coming from the economizer and going into the boiler is 400-500 degrees F.

11. They have a primary, secondary, and tertiary superheater with desuperheaters in between stages of the superheaters if the load drops to 50%

12. Their make-up water comes from the city of Monroe

13. If the temperature of the steam goes above 1090 degrees F. then there is an all fuel trip which shuts the unit off the fire

14. There is a flash tank similar to a boiler drum at the top of the tubes for wet steam at start-up

15. They use Phosphate and Hydrazine for chemical treatment

16. They have a 4 bed demineralizer

17. It takes 16 to 20 hours to start the boiler and turbine

18. The boiler is 210 feet high and has 25 to 30 miles of tubes

19. The boiler generates 5,000,000 pounds of steam per hour

20. 3/1000 to 7/1000 of an inch of vibration on the turbine will bring in an alarm

21. 18,000 miles per hour steam velocity in the first stage

22. 750,000 KWH of electricity per generator or 3,000,000 KW total for the plant

23. 140 coal cars per train @ 120 tons each equals 17,000 tons of coal which will last 14 hours

24. Monroe burns 23,000 tons of coal per day

25. They use 760 lbs of coal to produce 1000 KWH

26. The stator for the Westinghouse turbine weighs 385 tons, produces 914,000 KVA @ 26,000 volts, 20,296 amps

27. 26,000 volts at turbine to 345,000 volts distribution to 120,000 volts local to 13,200 volts to 4,800 volts.

28. They "bottle bore" the turbine rotor to remove impurities that settle in the middle of the forging, to allow for ultra-sonic testing and to allow for more even stress

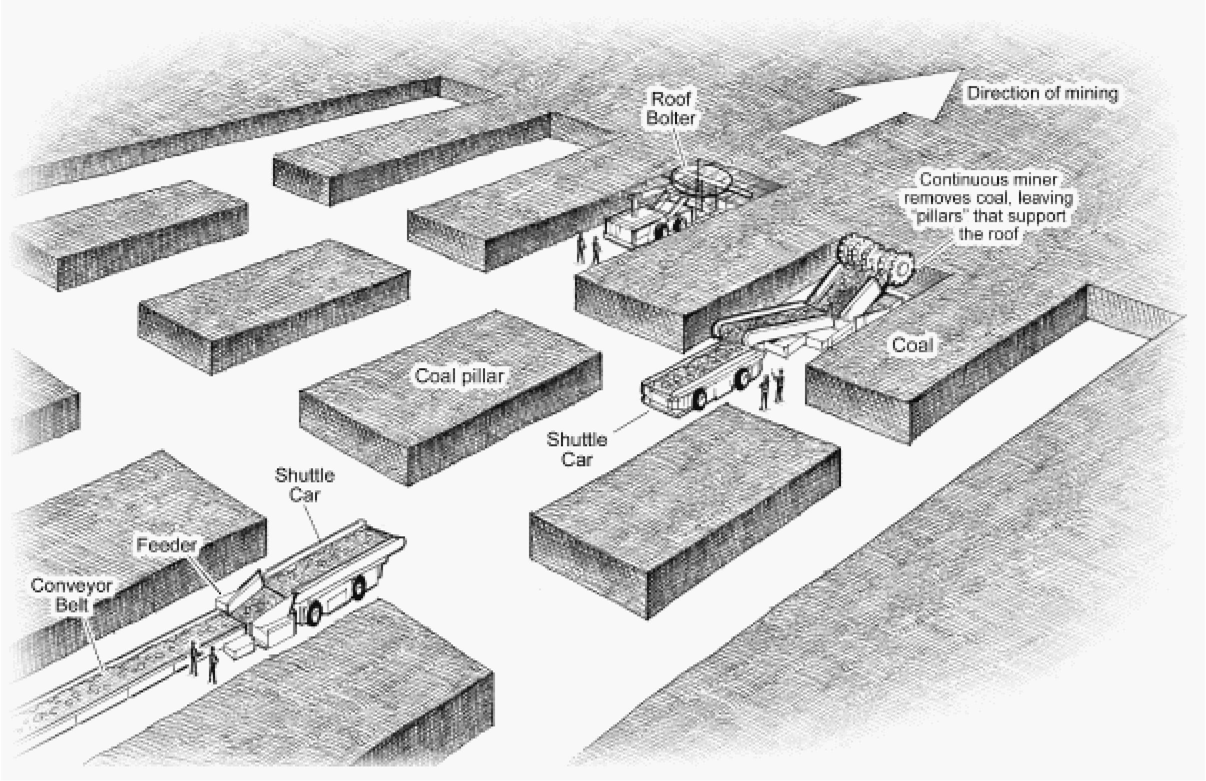
29. It takes 32 megawatts of electricity just to run the auxiliary equipment for one boiler-turbine set

30. Hydrogen Pressure varies from 65 to 70 psi. They adjust the pressure to cool the generator when the megavars of reactive power increase.

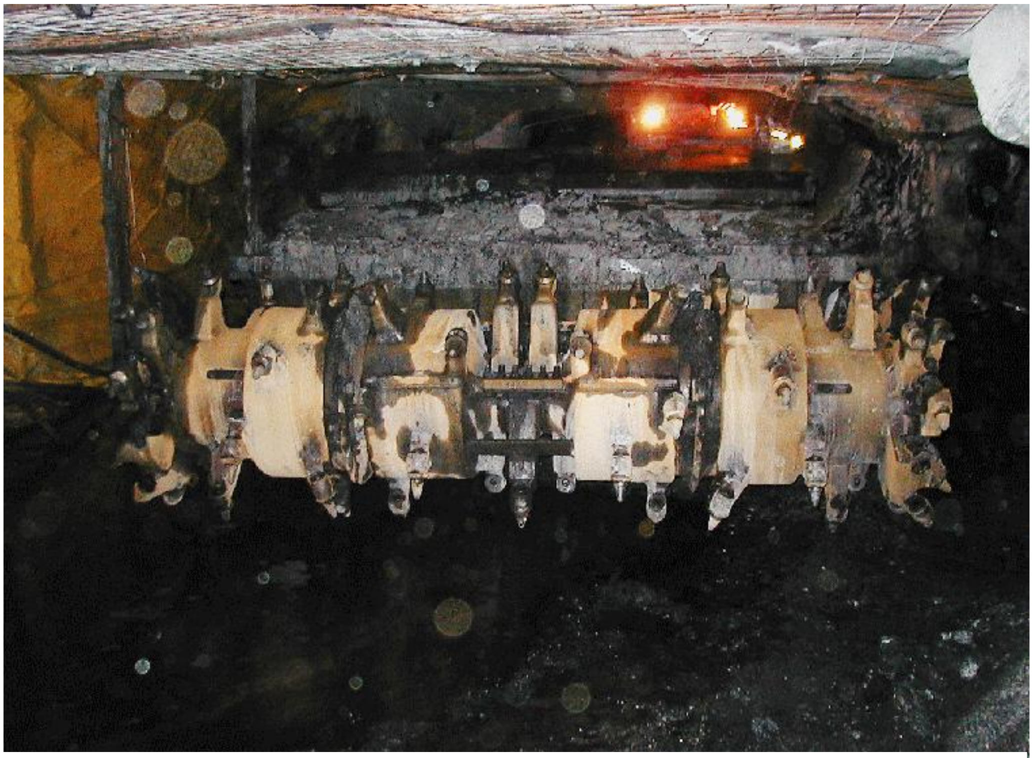
31. The oil pressure is 42 psi. the temp going to the bearings is 110 degrees Fahrenheit and the temperature leaving the bearings is 145 degrees F.

Explain in detail how coal is mined in the East.

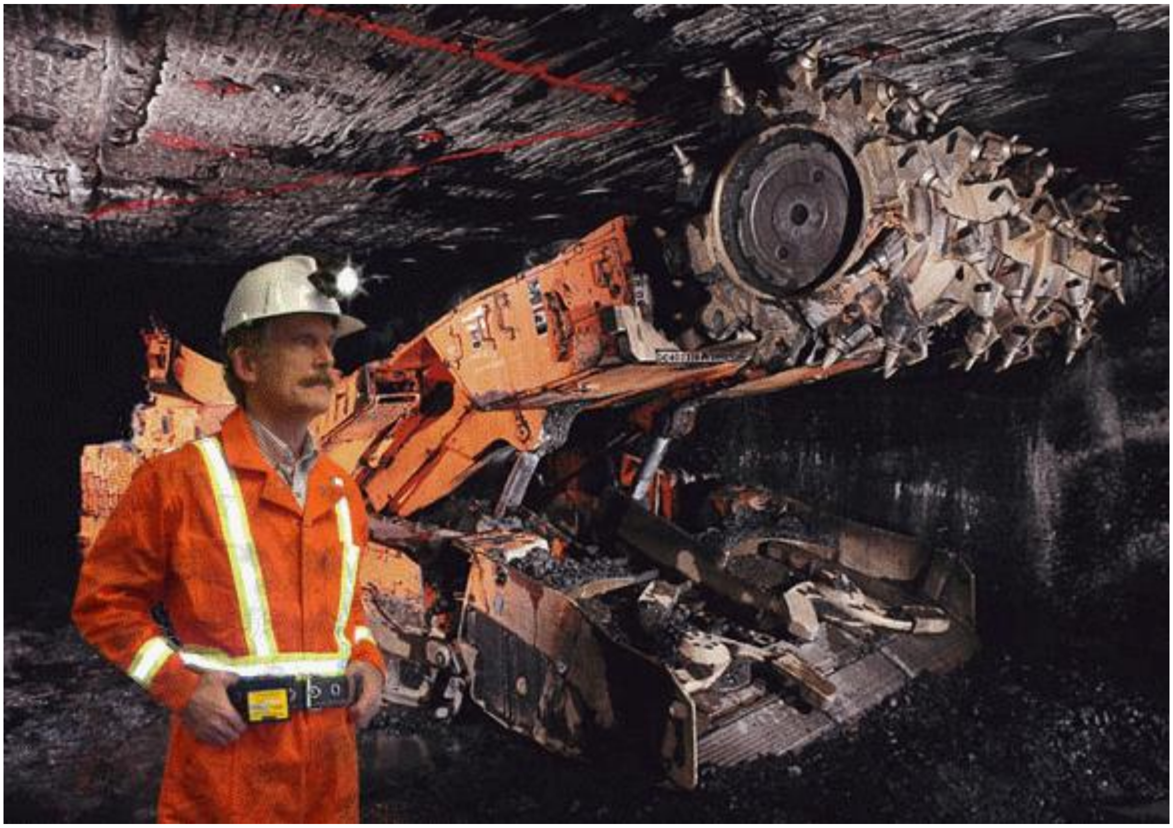
Modern underground coal mining methods use machinery known as continuous miners and longwall miners.



Room and Pillar mining using continuous miners

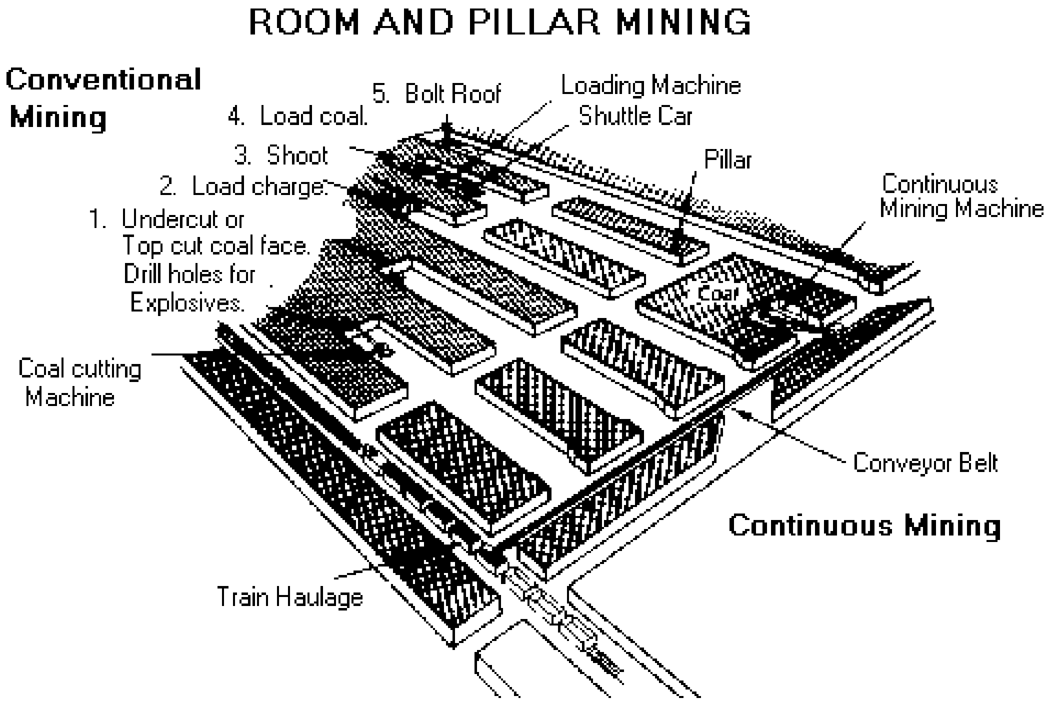


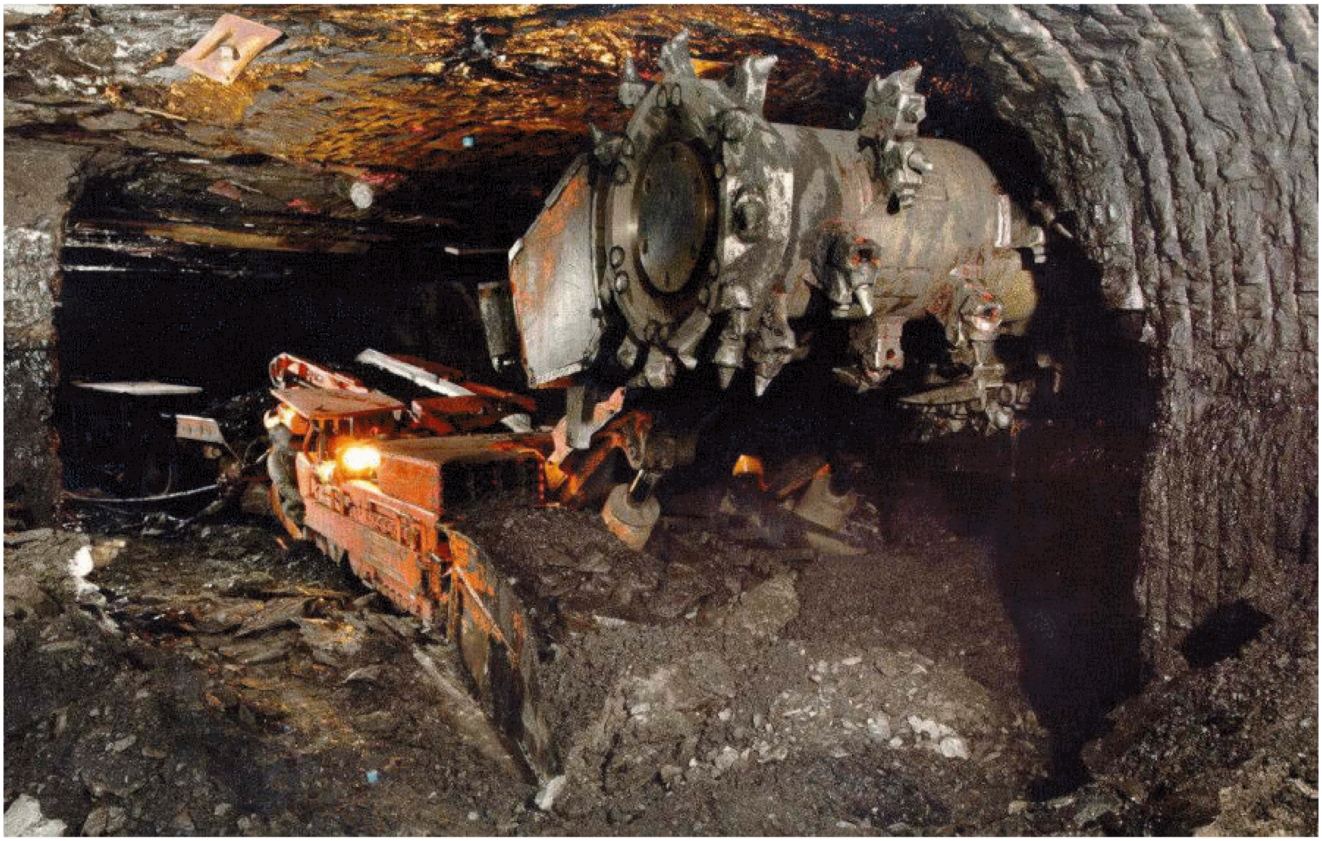
The business end of a continuous miner. Note the screen and the roof bolts on the top keeping the mine from collapsing



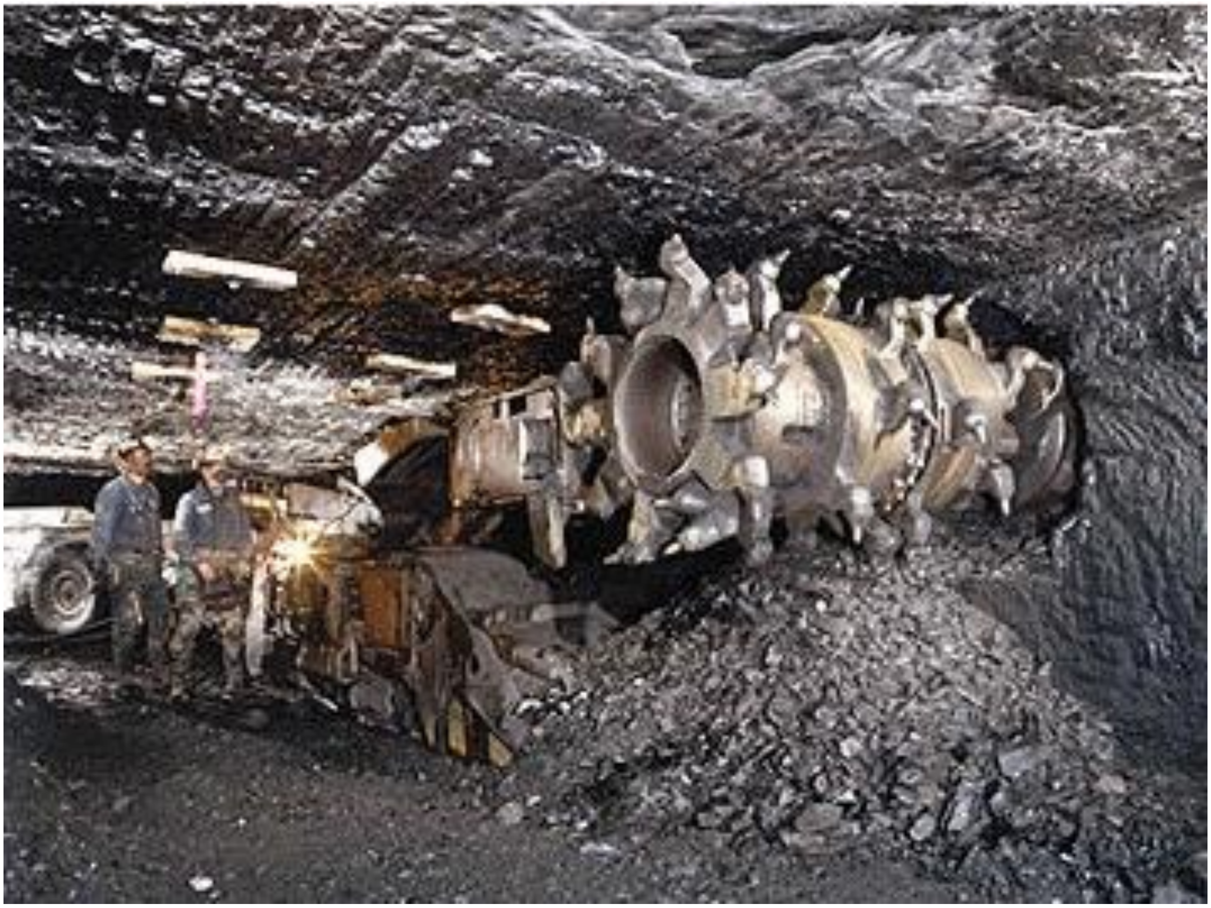
Continuous miner with pan underneath the cutting teeth. The arms in the pan move the coal to the drag chain conveyor in the center that moves the coal to the back to the miner where the shuttle car can pick it up and transport it to the main conveyors that move the coal out of the mine.

Continuous miners claw at the coal face, breaking the coal into small chunks. Some continuous miners are remote controlled with the operator standing nearby. Some coal is left to form a "room and pillar" where the coal that is left as the pillar supports the roof where coal has been removed. Long roof bolts are driven into the roof to prevent its collapse.

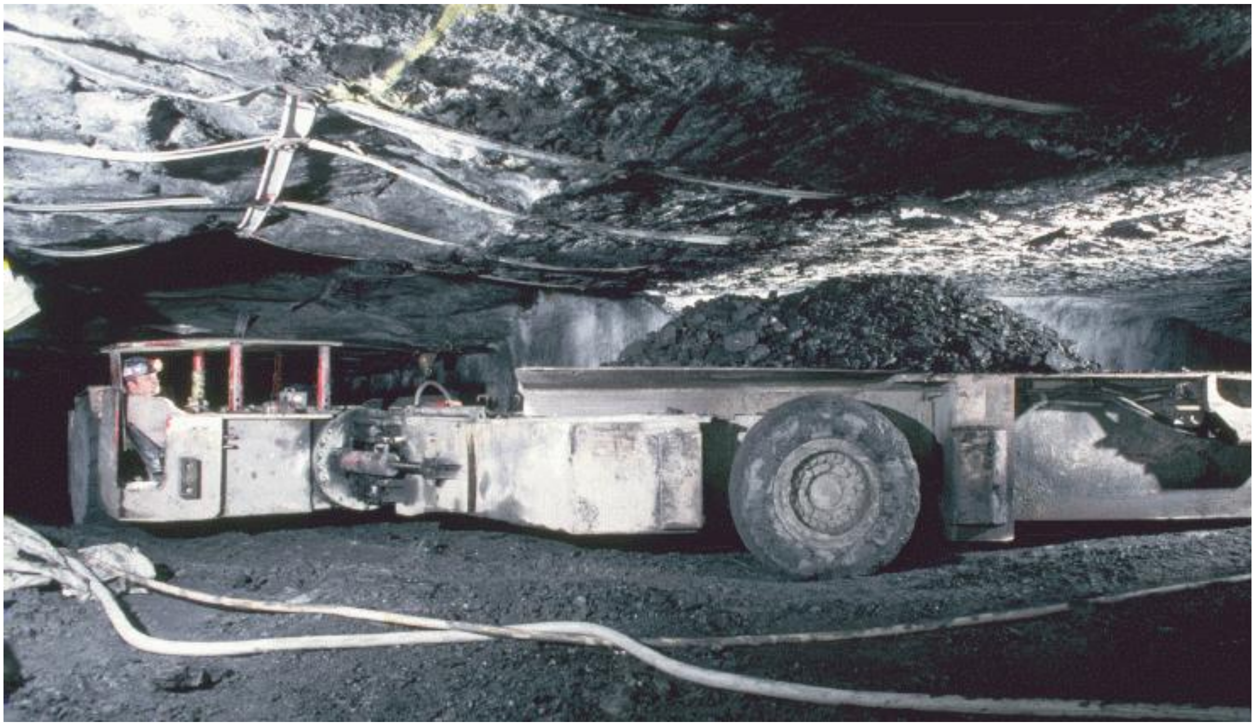




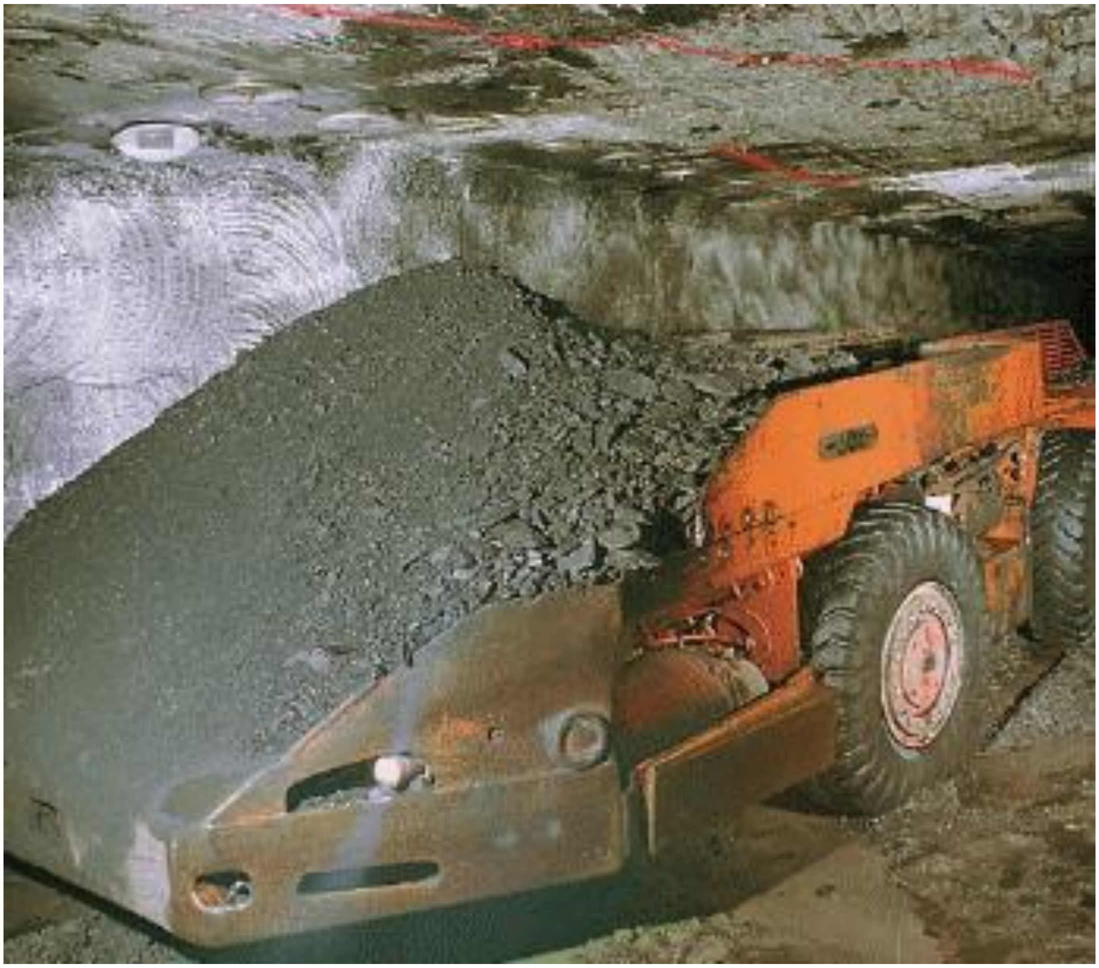
Continuous Miner in action. Note roof bolting and operator sitting in the back running the machine.



Continuous Miner with Operator using a remote control hung around his waist. This gives him freedom of movement to see how the cutting is progressing but he must be careful in tight areas or he may pinned between the continuous miner and the wall. Roof bolts and boards spread the weight overhead. You can see the shuttle car in the backround.



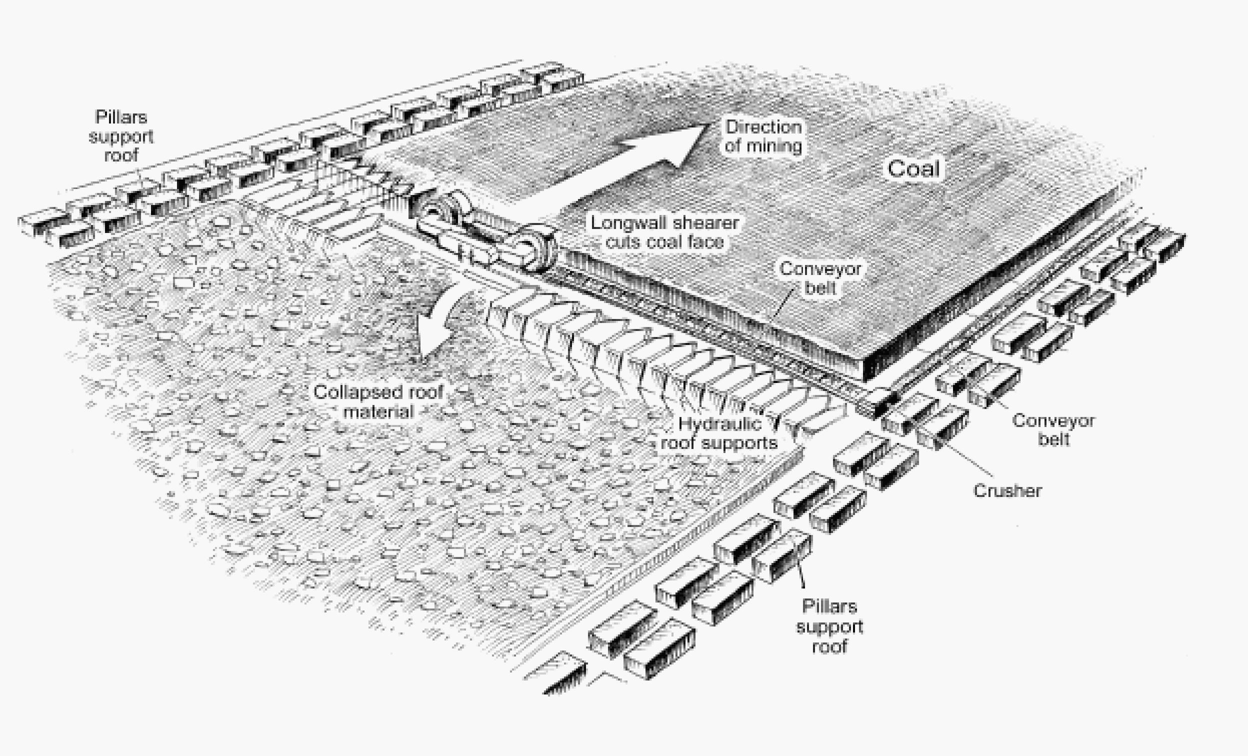
Coal Shuttle Car

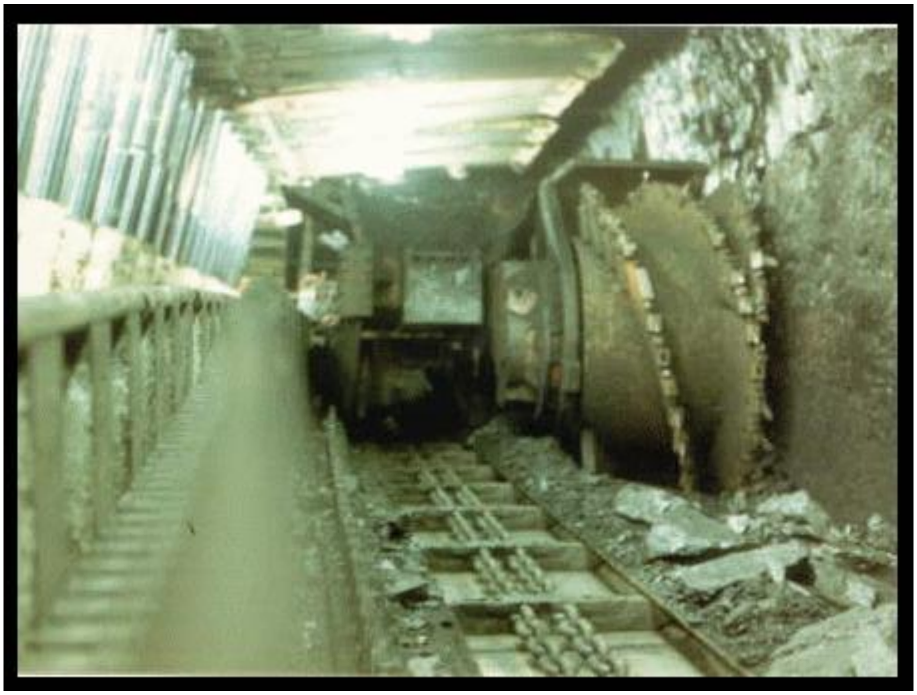


Coal Shuttle Car

Longwall Mining

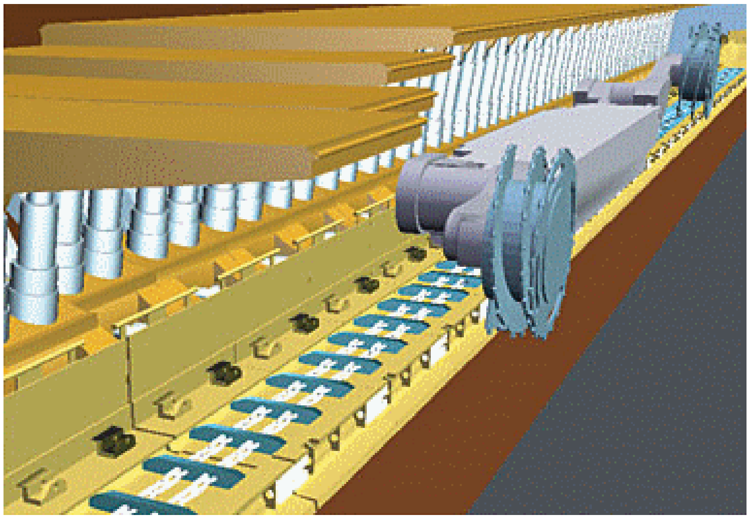
In longwall mining, a long series of hydraulically operated roof shields are placed keep the roof of the mine in place while the coal is extracted. The rotary cutters of the longwall miner run back and forth across the face of the coal seam, shearing the coal from the face. The sheared coal falls onto a drag chain conveyor and is moved back to the mine entrance.





Compare this picture to the diagram above. The rotary cutters on the right are cutting the face of the coal seam which falls in chunks onto the drag chain conveyor in the bottom center of the picture. The trolley in the center moves the cutters back and forth across the coal. The roof shields on the left and top of the picture keep the roof from collapsing until the machine is moved forward. Then the roof caves in behind the machine.

Longwall miner in action. Note how the arm moves up and down depending upon the thickness of the coal seam.

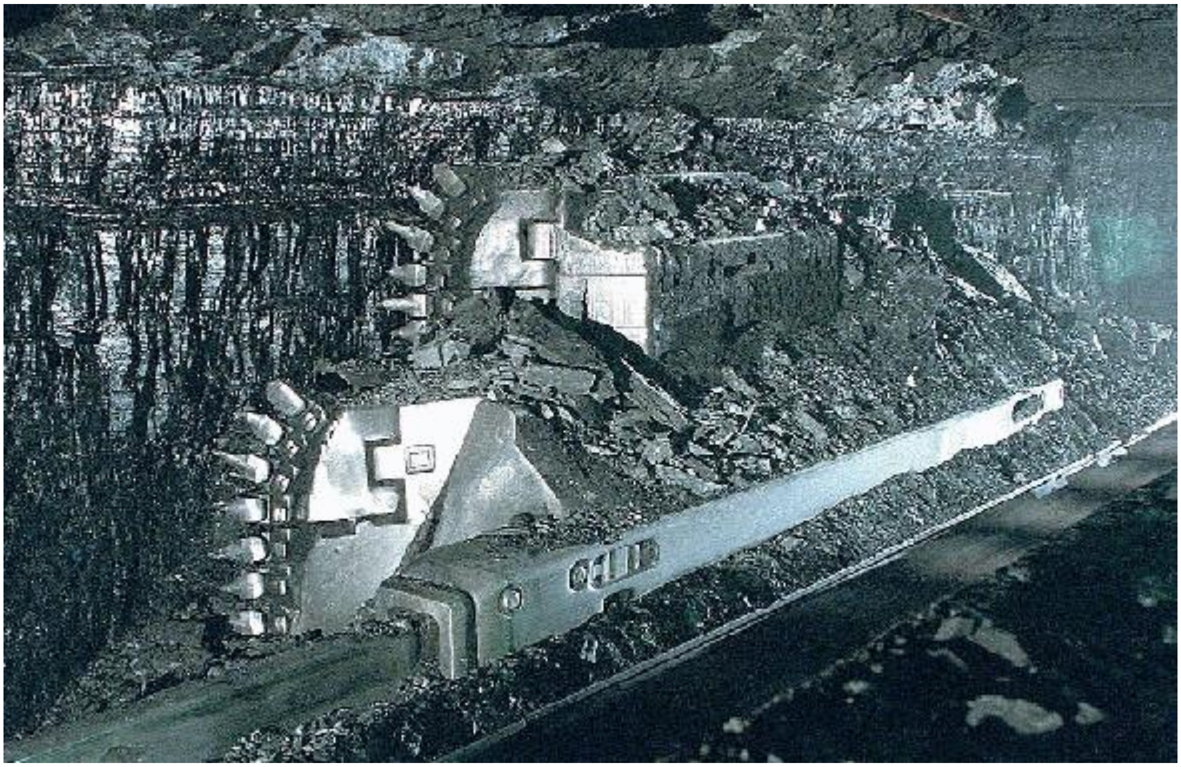


Longwall miner showing hydraulic roof shields and chain conveyor

Longwall operator wearing helmet and face shield with air filter

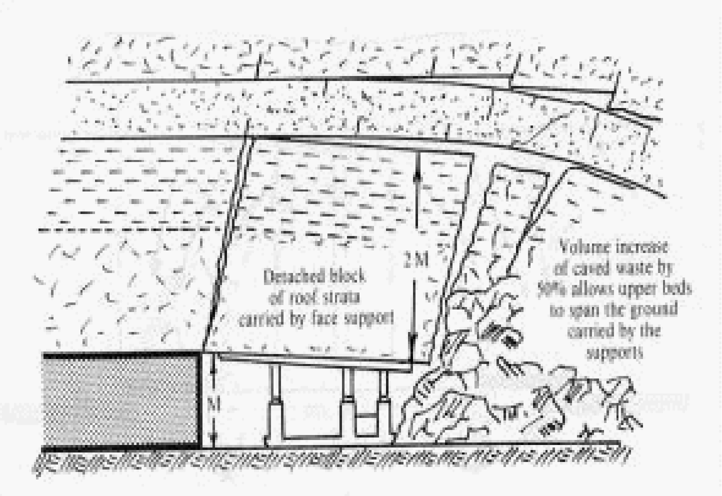
Longwall Plows

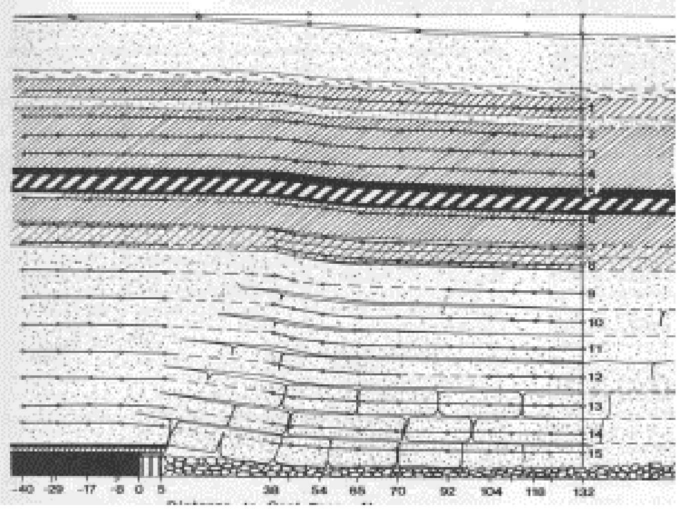
Sometimes plows are used instead of rotary cutters. These are very similar to longwall miners but the plow is basically a plate on a conveyor chain with sharp teeth that is shoved into and across the coal face to break off the coal. The teeth do not rotate. It has the advantage of being able to work coal seams of smaller height.

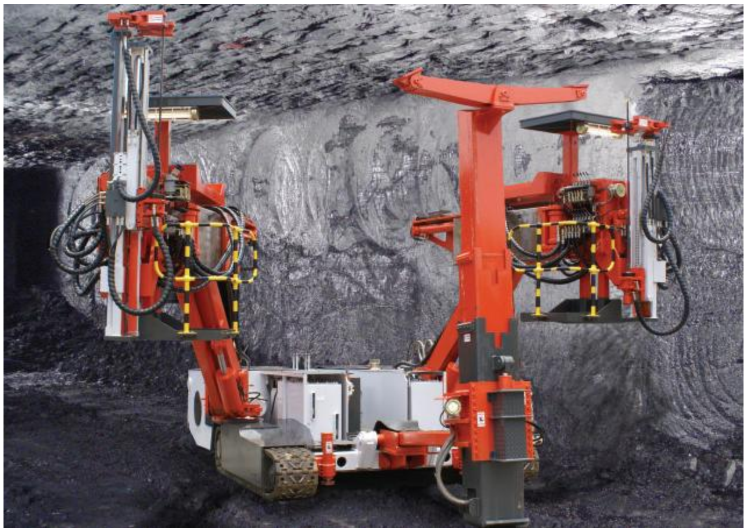


Longwall plow

Longwall mining has a bad reputation. Although it removes more coal than continuous mining, the effect of the collapsed mine destroys houses and streams as the earth drops 3 or more feet topside as the mine roof collapses. Water sometimes floods the mines.

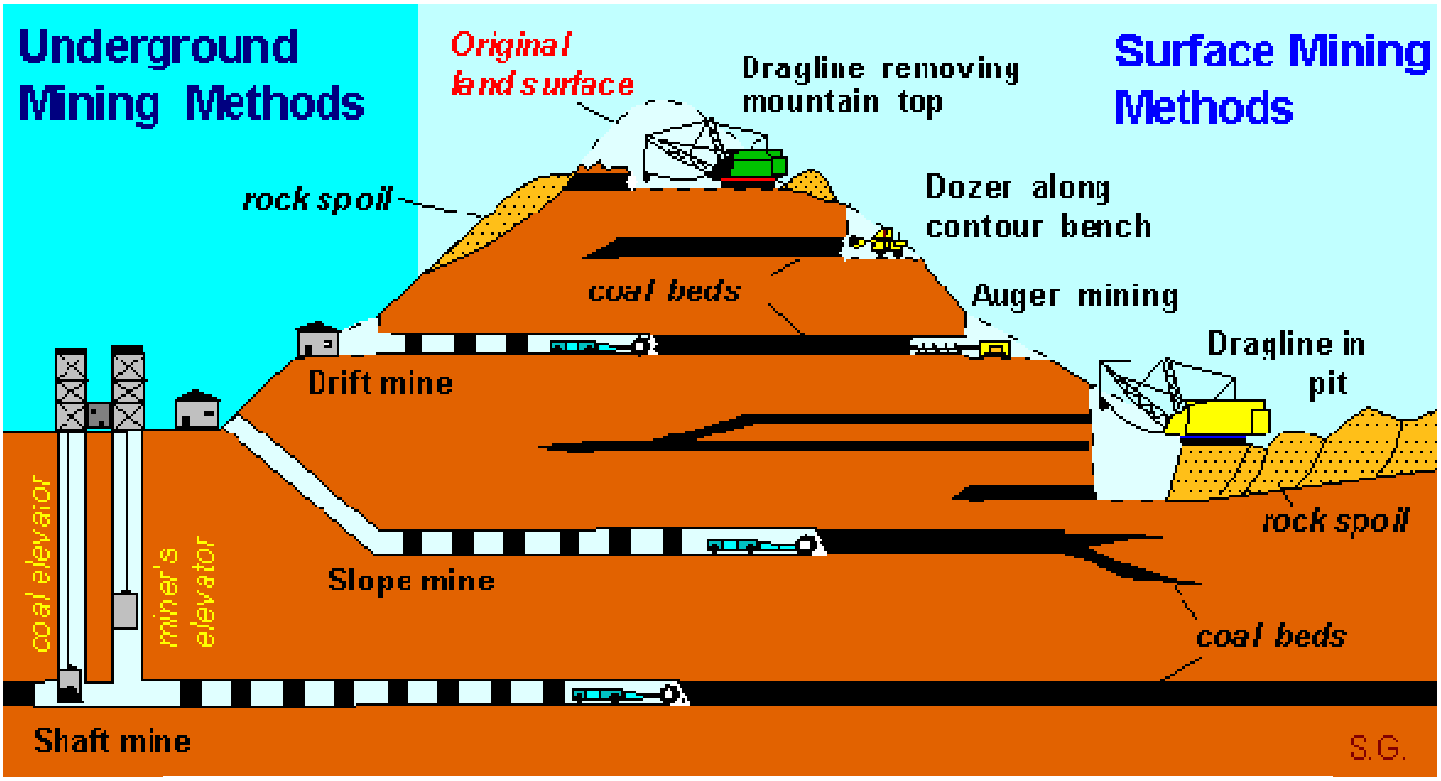






Twin boom hydraulic roof bolter. The bolts are around 8 feet long and are screwed together in sections if there is not enough headroom for longer rods.

Sometimes the roof bolts do not keep the roof from collapsing, leading to the death of the miner as this OSHA accident investigation drawing shows. Mining is still a very dangerous occupation.

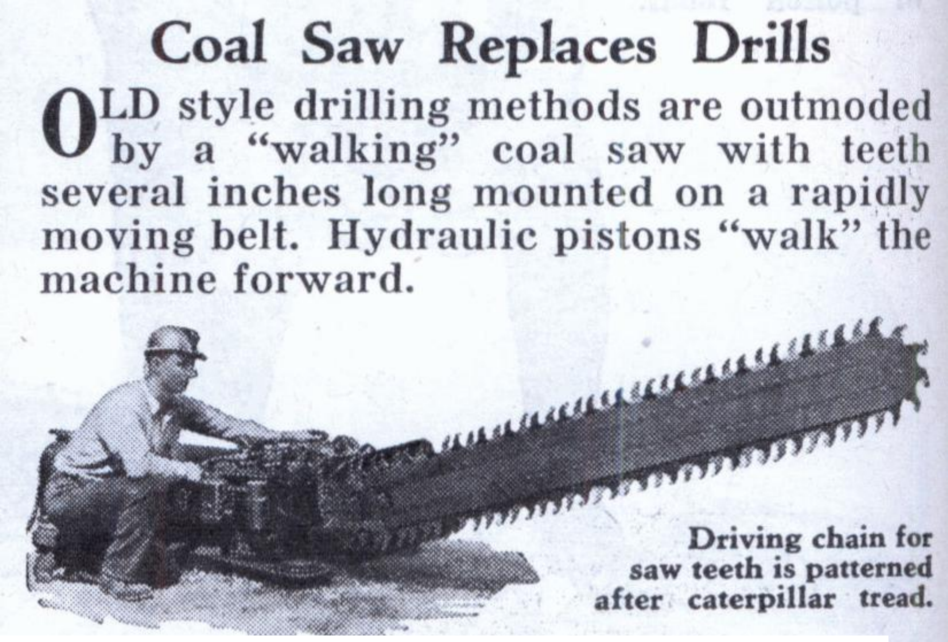


This diagram summarizes all the ways coal is mined in the East and West.

How is the coal mined in the Appalachian region?

In the Appalachian region, coal is predominantly mined underground. Shaft mines are most common with slope mines and drift mines used on seams closer to the surface. The tops of some mountains are blasted off and draglines, shovels and bulldozers remove the coal similar to the Western style of strip mining.

In conventional mining before the use of longwall miners and continuous miners, large saws were used to square off the floor or roof of the mine by top cutting or bottom cutting. Holes were then drilled in the face of the seam before blasting the coal and removing it with special front end loaders.

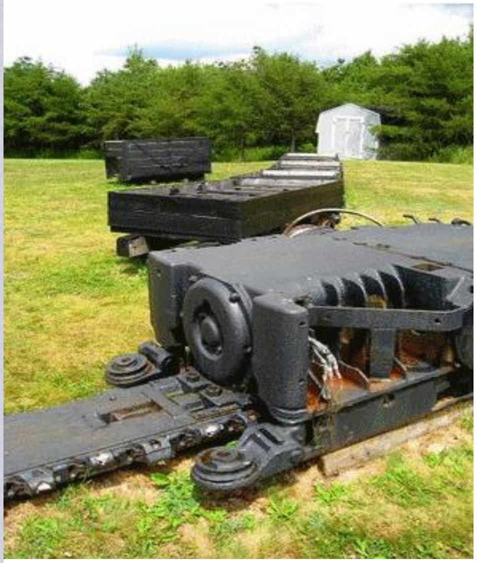


Coal Saw Replaces Drills

OLD style drilling methods are outmoded by a "walking" coal saw with teeth several inches long mounted on a rapidly moving belt. Hydraulic pistons "walk" the machine forward.

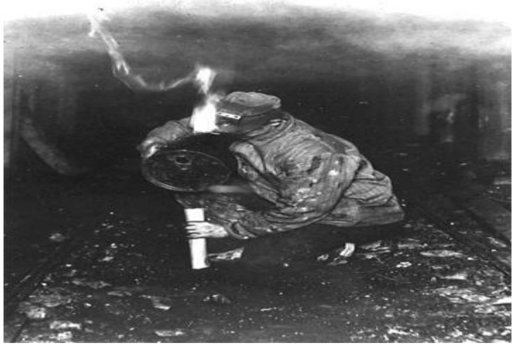
Driving chain for saw teeth is patterned after caterpillar tread.

In conventional mining, This saw would top cut or undercut the coal seam before blasting



The saw is in the position for undercutting the seam

This front end loader will scoop the coal after it is blasted.



Miner pouring blasting powder into a tube to insert in a hole for blasting the face of the seam into pieces small enough that a man can handle. Note the open flame on his helmet. Probably a job they gave the new guy.

Specially built cars get the miners to the working face of the mine

Mountaintop removal and strip mining are controversial in the Eastern States (such as this surface mine in Kentucky), although the land is reclaimed after the coal is removed.

Eastern Strip Mine. Notice the landslide on the left. These landslides into the pit can bury men and machinery.

How is coal mined in the Western States?

Just like the Powder River Basin, in the Western States, coal is mined by strip mining or open pit. In strip mining the overburden is removed by large diesel and electric shovels, and the coal by smaller shovels. If the coal is hard, it is blasted prior to loading. Small strip mines frequently load coal of inferior quality. Outcrop coal is weathered, frequently mixed with impurities, and of low calorific value. Outcrop coal is coal that has its seams already exposed to the outside air.

Blue Combustion Engineering page 1·8

Which coal has higher BTU value, Eastern or Western coal?

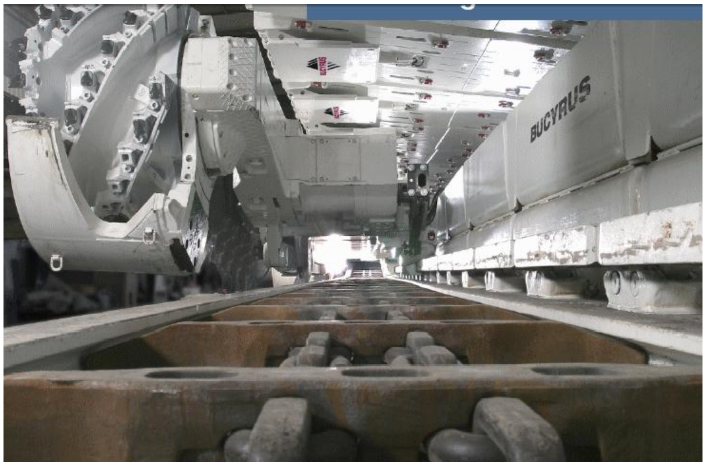
Coals in the East are higher in BTU content than the Western coals. Coals from Pennsylvania at 12,800 BTU to 14,400 BTU, and coals from Kentucky at 12,500 BTU to 14,000 BTU have higher heating values than Western coals at 9,900 BTU to 10,700 BTU per pound.

Blue Combustion Engineering pgs. 2·14 - 2·16

Which coal costs more per pound, Eastern or Western?

East dominates in quality, West in quantity. From a view point of quantity, the largest reserves in the U.S. occur in the three areas known as the Northern Great Plains, Rocky Mountains, and Pacific Coast provinces, whose deposits far surpass in quantity than those of the two eastern provinces. Coal in the West is strip mined which is cheaper than underground mining. Therefore, Western coals are cheaper.

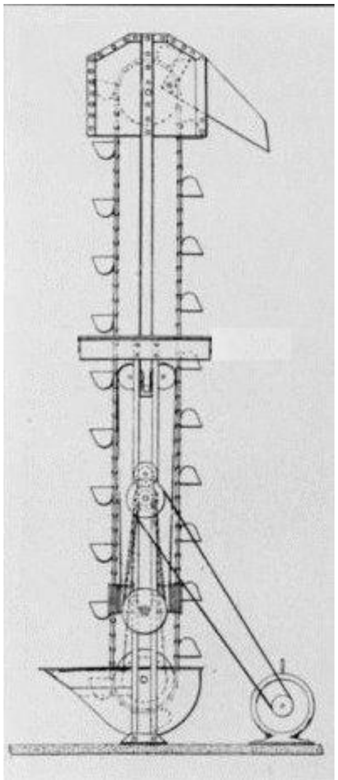
Blue Combustion Engineering page 2·38



Coal from the underground mine is sent to the surface with a series of drag link conveyors, shuttle cars, belt conveyors and elevators. The next stop is the coal cleaning plant. Note the longwall cutter on the left and the roof shields overhead and on the right.

Caterpillar 797B, the worlds' biggest coal dump truck. Surface or strip mines use these trucks to unload onto conveyors to go to the coal cleaning plant.

Underground conveyors carry the coal to the elevators

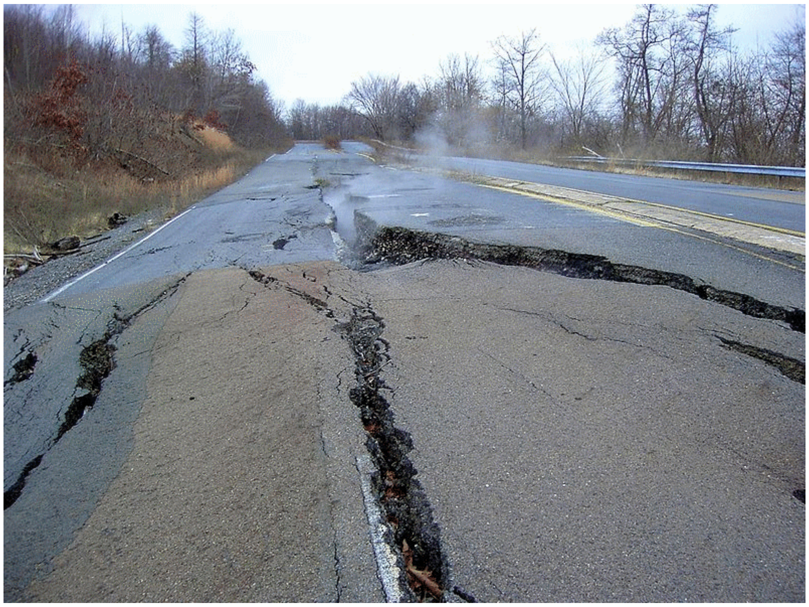


Bucket elevators bring the coal to the surface to land on conveyors going to the cleaning plant

How do you handle a fire in a coal mine?

In May 1962, the Centralia Pennsylvania Council hired five members of the volunteer fire company to clean up the town landfill, located in an abandoned strip mine pit next to the Odd Fellows Cemetery. This had been done in previous years when the landfill was in a different location. The firefighters, as they had in the past, set the dump on fire, and let it burn. Unlike in previous years, however, the fire was not extinguished and the fire spread into the anthracite coal mines from a vein that was close to the surface. Efforts to isolate, flood with water or wall up the mine shafts were unsuccessful. In 1979, after one particularly ill-conceived engineering project, the fire broke through an underground barrier installed in earlier years and the fire moved under the town itself, sending dangerous gases into one home after another and causing the ground itself to collapse. In 1983, there was fire under about 350 surface acres. By 1991, this area had almost doubled. The worst case scenario is that 3700 surface acres will be affected and the fire will last a hundred years. 26 homes along Route 61 west of town were bought in April of 1991. There are no future plans to fight the fire.

Anthracite fire burning underground in Centralia

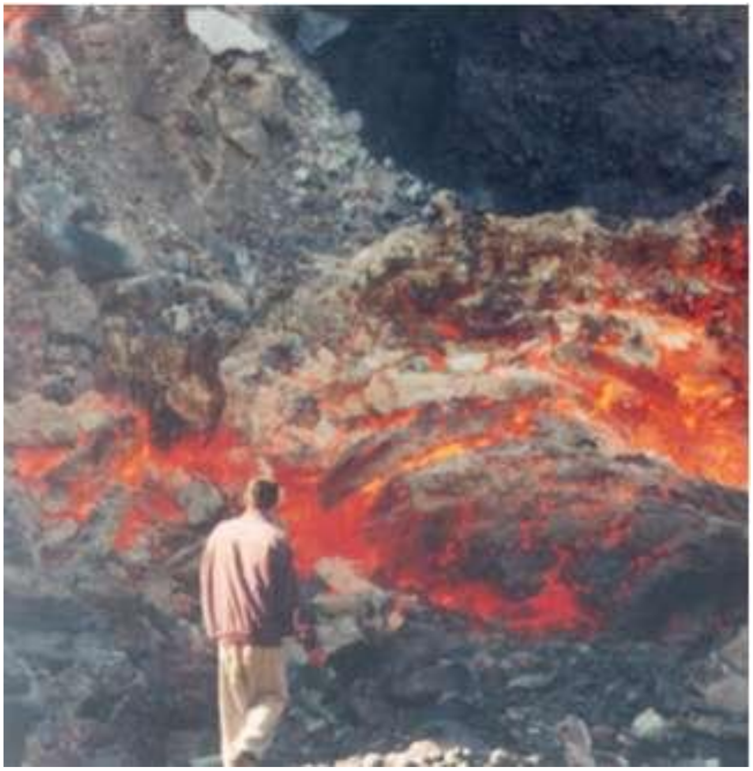


Smoke comes up through the cracked asphalt in Centralia

The fire breaks through to the surface at Centralia

And you thought the roads were rough in Michigan

Thousands of underground coalmine fires are believed to cover an area of 280 square miles in China. They consume as much as 20 million tons of high-quality coal and another 200 million tons of coal storage each year. The fires, often smoldering in coal seams on or just below the surface, have shaped the landscape of coal-rich regions in China for millennia. The layers of coal can go on for miles underground, with fuel to burn for centuries. The smoke darkens already polluted skies. The fires emit poisonous gases and can even make the earth cave in; swallowing roads, homes, animals and humans The oldest is believed to be at Baijigou, northwest China, and has been burning since the Qing Dynasty.



After a three-year effort and untold quantities of water, Chinese firefighters have extinguished a fire that had been burning underground in a coalmine for more than 50 years. Firefighters finally beat the fire by boring into the coal seam and flooding it with water and slurry. They then capped the mine shafts to starve the flames of oxygen. The smoldering furnace 330 feet underground at the second-largest coalfield in Xinjiang had released more than 70,000 tons of toxic gases annually since the 1950s.

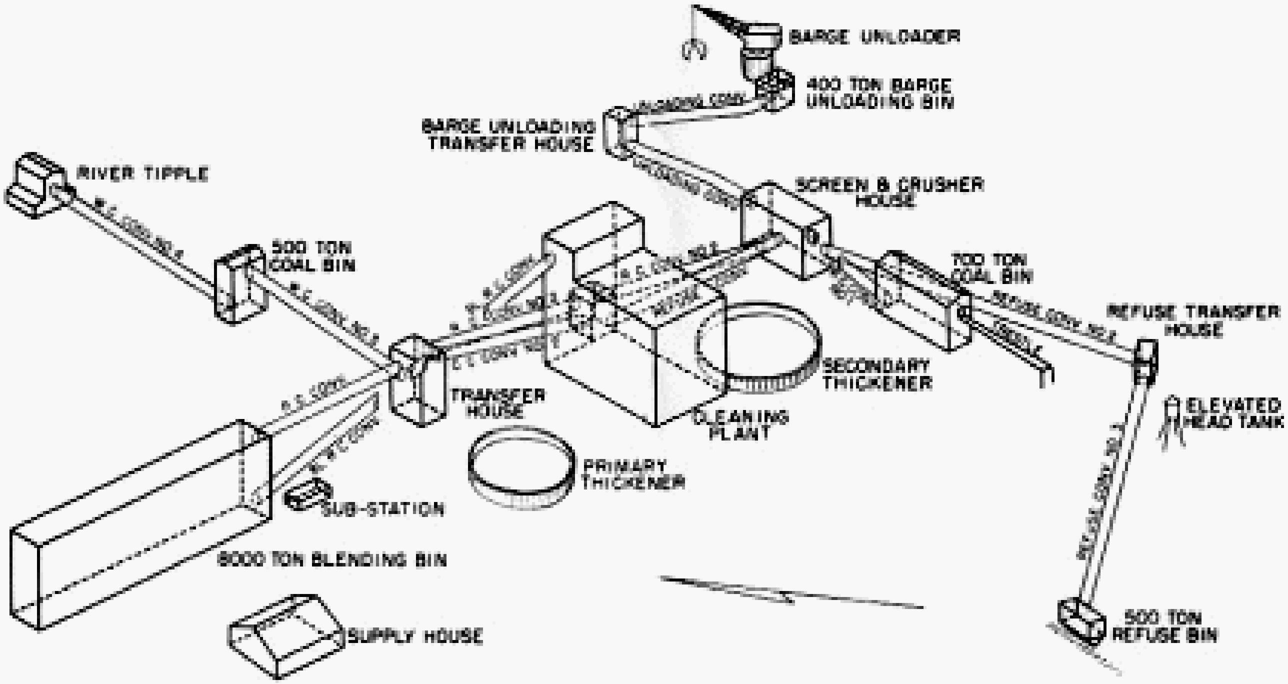
China, the world's largest coal producer, has many uncontrolled underground coal fires. These fires consume over 100 million tons of coal each year. That's more than twice the amount of coal China exports during that same number of months. And, each year, these same fires contribute greatly to global warming, releasing around 360 million tons of carbon dioxide into the atmosphere (That, on average, is about the same as that emitted by all the cars and light trucks in the United States).

China will not make a binding commitment to reduce carbon emissions, putting in jeopardy the prospects for a global pact on climate change. Officials from Beijing told a UN conference in Bonn that China would increase its emissions to develop its economy rather than sign up to mandatory cuts.

Describe how coal is cleaned and separated from impurities.

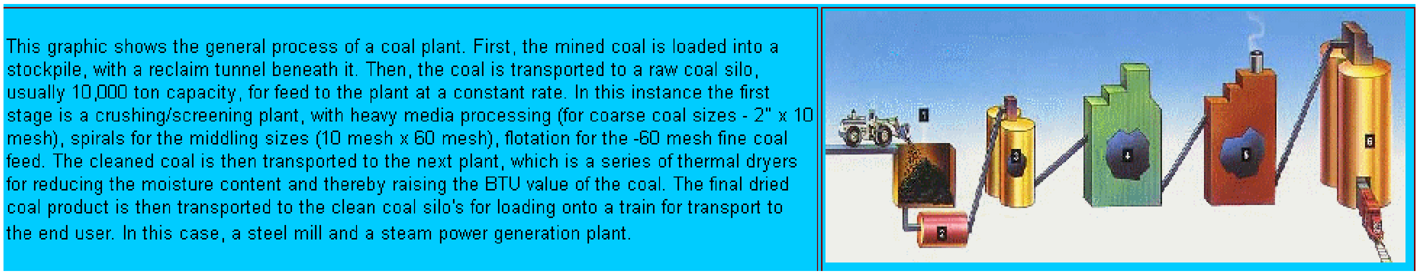
Gravity concentration is achieved because heavier particles settle farther and faster than lighter particles of the same size in a fluid medium. Coal and impurities may be segregated by their inherent differences in specific gravity. Jigging, a pulsating current of water is pushed upward in a regular, periodic cycle through a bed of raw coal supported on a screen plate. The bed is expanded and contracted with this process and the heavier impurities settle faster than the coal. Tabling, a pitched table is mounted so it may be oscillated at a variable frequency and amplitude. A slurry of coal and water is continuously fed to the top of the table and is washed across it by the oncoming feed. Diagonal bars, or riffles, are spaced perpendicular to the flow of particles. The coal- water mixture and oscillating motion of the table create a hindered settling environment in which the lower gravity particles rise to the surface. Higher specific gravity particles are caught behind the riffles and transported to the edge of the table, away from the clean coal discharge. Dense media separation the raw coal is immersed in a fluid with a specific gravity between that of the coal and the refuse. The specific gravity differences cause the coal and refuse to migrate to opposite regions in the separation vessel. In coal preparation, the heavy media fluid is usually an aqueous suspension of fine magnetite in water. Dewatering is a key step in the preparation of coal. Reducing the fuel's moisture content increases its heating value per unit weight. Because coal shipping charges are based on tonnage shipped, a reduction in moisture content results in lower shipping costs per unit heating value.

Steam, Its Generation and Use by Babcock & Wilcox Solid fuel processing and handling pages 11-5, 11-6

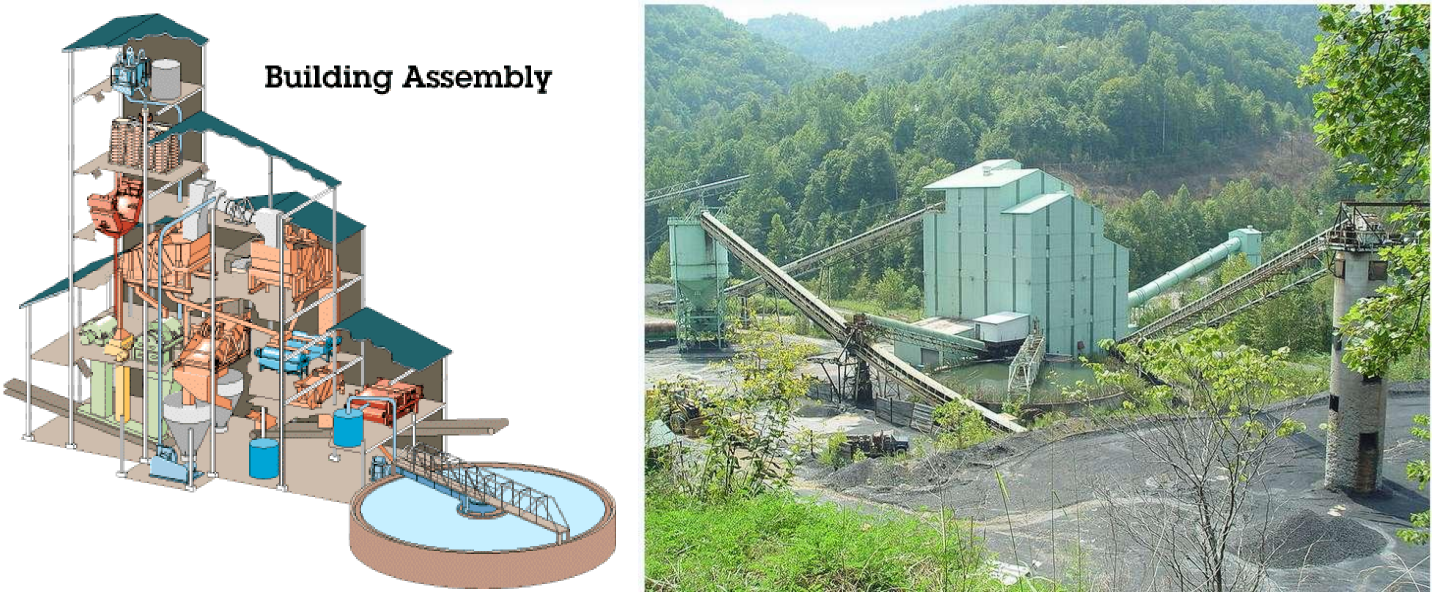


MAPLE CREEK PREPARATION PLANT SURFACE FACILITIES

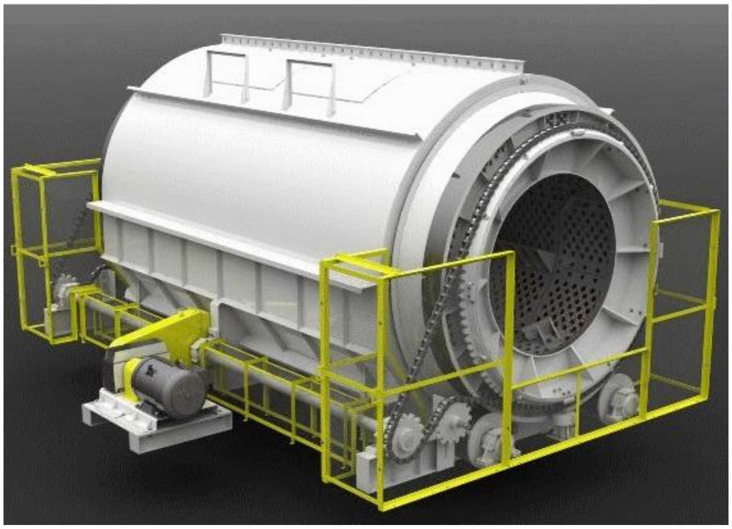
Once coal is brought to the surface it is sent to a Coal Preparation plant at the mine. Continuous and longwall miners cannot bring up pure coal because it lies between layers of rock. Some bands of impurities are within the seam itself and are taken along with the coal. Rock mixed in with the coal must be removed before shipment to the customer.



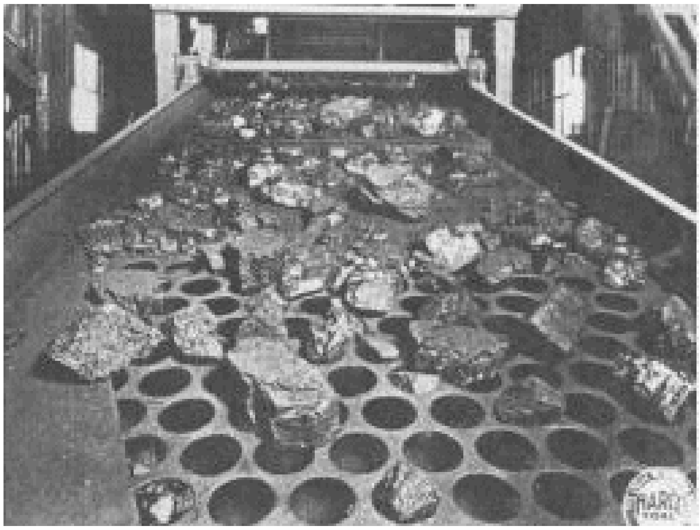
This graphic shows the general process of a coal plant. First, the mined coal is loaded into a stockpile, with a reclaim tunnel beneath it. Then, the coal is transported to a raw coal silo, usually 10,000 ton capacity, for feed to the plant at a constant rate. In this instance the first stage is a crushing/screening plant, with heavy media processing (for coarse coal sizes - 2" x 10 mesh), spirals for the middling sizes (10 mesh x 60 mesh), flotation for the -60 mesh fine coal feed. The cleaned coal is then transported to the next plant, which is a series of thermal dryers for reducing the moisture content and thereby raising the BTU value of the coal. The final dried coal product is then transported to the clean coal silo's for loading onto a train for transport to the end user. In this case, a steel mill and a steam power generation plant.



Coal Preparation Plant. Note the settling pond in both pictures.



Bradford Breaker breaks up large size coal



Sorting table separates the coal into different sizes

Since the very early days of mining, attempts have been made to improve the quality of coal by removing slate. These efforts were made in the underground mines until the advent of mechanical mining, supported by hand picking outside of the mine.

The Good Ole days: hand picking impurities as the coal came from the mine

No matter what job you have, there will always be a boss looking over your shoulder

Coal cleaning is a term applied to the removal of the foreign impurities of coal. Impurities occur in coal in either of two forms, inherent impurities which are not removable by cleaning and foreign impurities which can be removed or materially reduced by some one or more of the different methods of coal cleaning.

Coal cleaning equipment can be divided into two general classes, that using wet methods and that using dry methods of separation.

Wet methods are: Chance Sand Floatation, jigs, and wet tabling.

Dry methods are air tabling.

CHANCE SAND FLOTATION PROCESS

The Chance Sand Flotation Process was invented by T. M. Chance and is a commercial application of the float and sink method of separation. The process is based upon obtaining and maintaining a mixture of sand and water of such a specific gravity that the coal will float and the foreign impurities having a higher specific gravity than the coal, will sink. The Chance Coal Cleaner consists of a conical separating tank designed to hold the mixture of sand and water; de-sanding shakers for removing the sand and water from the coal and refuse. A reservoir collects the sand and water coming from the desanding equipment and a pumping system for returns the sand and water to the conical separating tank.

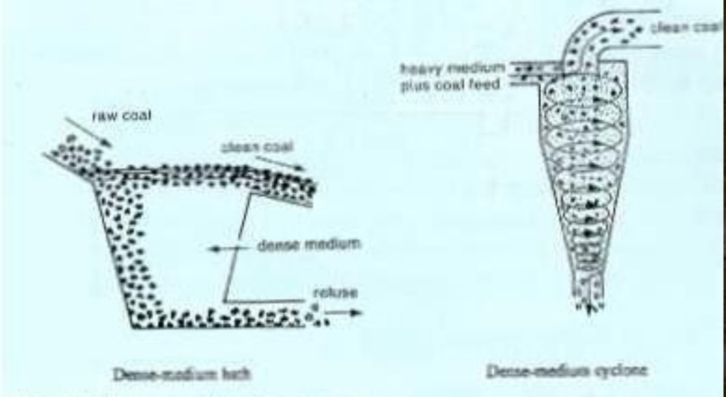
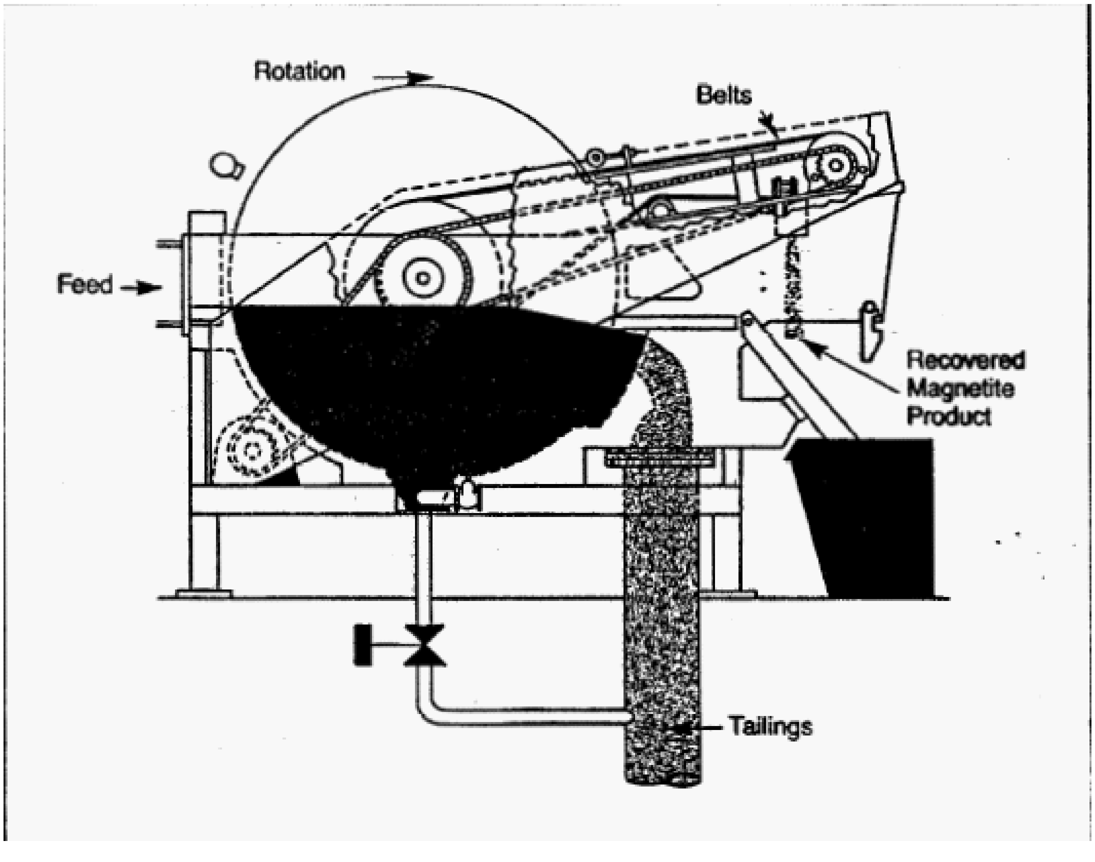


Fig. A2 Dense-medium Separators

Chance Coal Cleaner

CHANCE COAL CLEANER INSTALLATIONS
In most installations of this type at least two cones are employed, one receiving the coal between 1 inch and 41/2 inches and size and the other taking the coal between one-sixteenth and one inch in size. By the use of two or more cones a better separation between the coal and the slate is obtained. From the cones the cleaned coal passes to the de-sanding equipment where practically all the sand and water are removed and thence to the screens for a final sizing before shipment. The refuse is discharged at the bottom of the cones into a water sealed conveyor from which it is discharged onto the shakers and from there is deposited into some kind of dumping apparatus. Practically all of the Chance Coal Cleaner Installations are in the anthracite regions.

The first washing technique was imported from Europe, followed by the introduction of the "Chance" washer. The latter was an excellent washer utilizing sand and water as a medium, which has since been displaced by the "heavy media" process using magnetite.



Magnetite is used because it is reasonably inexpensive, stable, non-toxic, effective on coals of varying quality, and can be recovered for reuse.

Because the magnetite recovered from the rinse screens is diluted by sprays, it is processed in magnetic separators for recovery of the solid mineral. Each washer (bath and cyclone) retains its own recovery system, which includes sumps, pumps, and magnetic separators. The separator is a shaft mounted steel drum containing an interior fixed magnet. The cylinder rotates within a vessel containing coal slurry and magnetite, retrieving solid magnetite from the slurry by virtue of the magnetic qualities of the magnetite and the magnetic field within the drum.

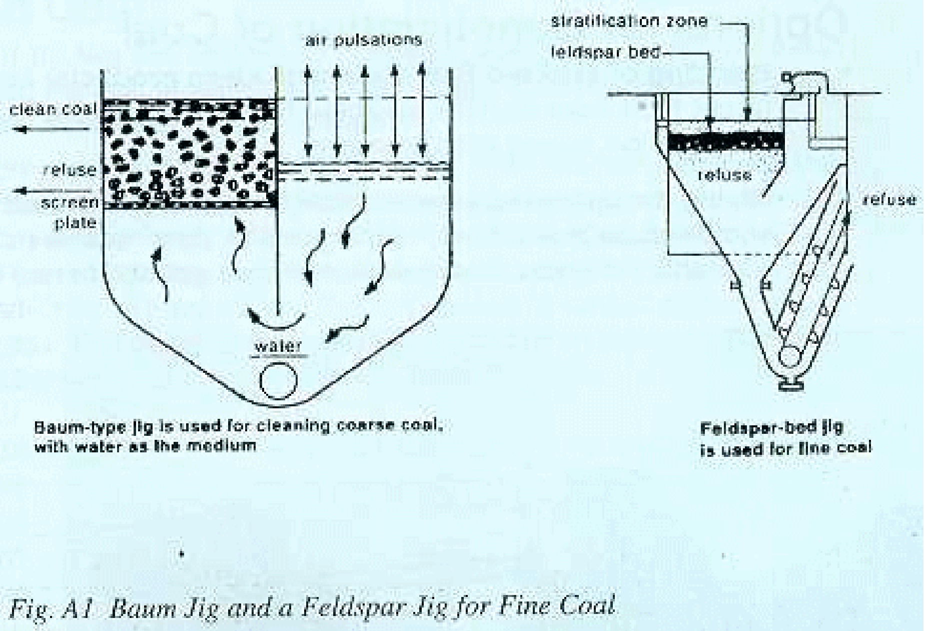
JIGS

Jigs were the first means of coal cleaning of which there is any record having been used in the early part of the nineteenth century. The jig is an apparatus for classifying materials according to their specific gravities by means of a pulsating current of water. After washing, the coal is dewatered to a moisture content of about 9 per cent.

The methods operate by differences in specific gravity. Jigs rely on stratification in a bed of coal when the carrying water is pulsed. The shale tends to sin, and the cleaner coal rises. The basic jig, Baum Jig, is suitable for larger feed sizes. Although the Baum Jig can clean a wide range of coal sizes, it is most effective with coal sized from .4 to 1.3 inches. A modification of the Baum Jig is the Batac Jig which is used for cleaning fine coals. The coal is stratified by bubbling air directly through the coal-water-refuse mixture in this cleaning unit.

For intermediate sizes the same principles are applied, although the pulsing may be from the side or from under the bed. In addition, a bed or hard dense mineral is used to enhance the stratification and prevent remixing. The mineral is usually feldspar, consisting of lumps of silicates of about 60 mm size. Figure A1 shows a Baum Jig and a feldspar Jig for finer coal.

Jigs offer cost effective technology with a clean coal yield of 75-85% at about 34% ash content. The jigs are used more frequently than dense-medium vessels because of their larger capacities and cheaper costs.



Baum-type jig is used for cleaning coarse coal, with water as the medium

Feldspar-bed jig is used for fine coal

Fig. A1 Baum Jig and a Feldspar Jig for Fine Coal

WET TABLING

Table concentration is especially adapted to the cleaning of fine coal. The Deister concentrating tables, are in general use in coal washing plants. A peculiar reciprocating motion is imparted to the table by means of a cam action. This motion causes the coal to flow across the table and a separation is affected according to specific gravities, by this motion, the flow of water across the table, and the riffles on the surface of the table. The big advantage of wet concentrating tables is the fact that the operator can observe and control the action of the table at all times. Concentrating tables consume little power and have a low initial cost, and as a result are quite extensively used in coal washing plants.

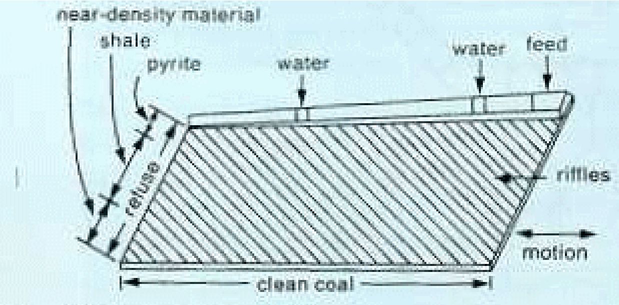
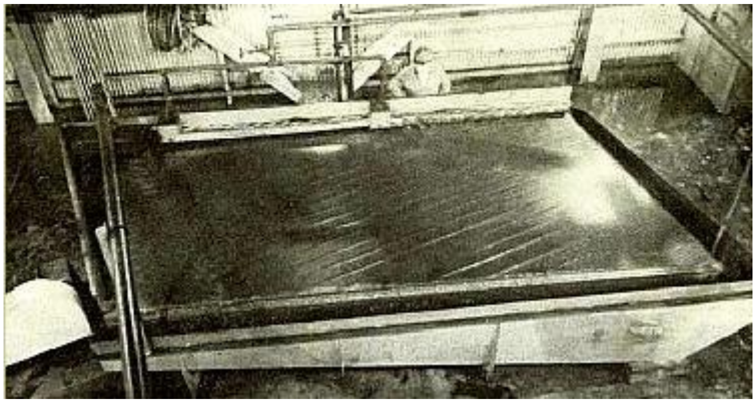
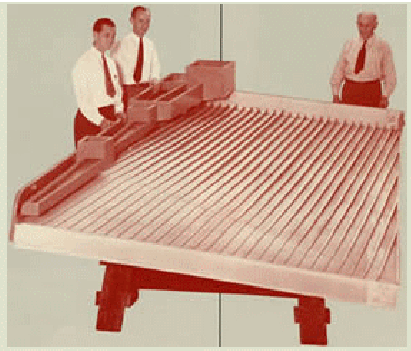


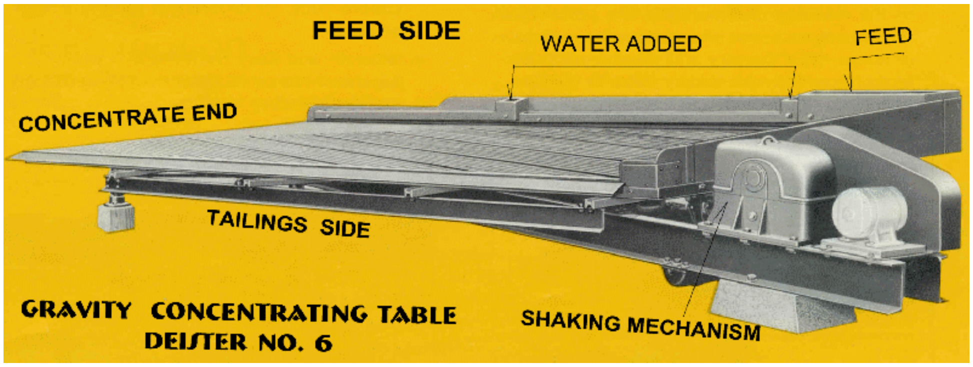
Fig. A4 Concentration Table



The adoption of Deister tables near the middle of the century to wash fine coal required supplementary equipment including centrifuges, froth flotation devices, disc filters, thickeners, cyclones, and thermal dryers.



[left to right] Irwin Deister Sr., Emil Deister Jr., Emil Deister Sr. - circa 1930



Emil Deister built his first separating table in his basement. This differential-motion ore-separating table had riffles attached to its surface. The riffles collected the heavier ore particles and conveyed them in one direction toward a collector, while water washing across them carried the lighter impurities away.

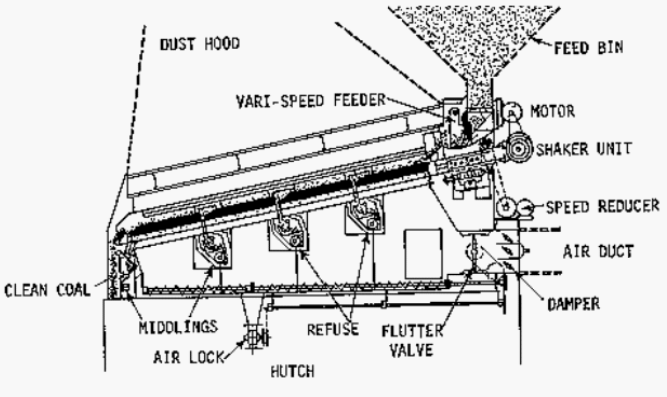
PNEUMATIC TABLING

Pneumatic tables employ the same principles as the wet concentrating tables, except that the water in the wet table is replaced by air in the Pneumatic table. The Arms Air Concentrator is typical of this type of table. The deck of the Arms table is made up of punched plates and screen cloth dressings through which air, as the separating medium, is applied to the coal. Riffles are mounted on metallic screen cloth and serve the same function as on the wet tables. The greatest advantage claimed for the pneumatic tables is the fact that no additional moisture is added to the coal in the process of cleaning, and thus the dewatering problem and the trouble with freezing in transit in winter are avoided.

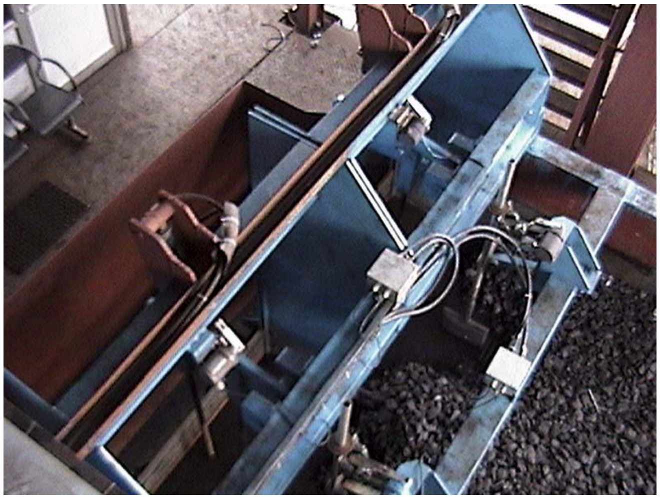
The tendency toward mechanization and coal cleaning is having a very noticeable effect upon the coal industry. It is reducing the number of men underground per ton of coal mined. It is resulting in the employment of a greater percentage of skilled labor, and finally it is producing a great need for more technically trained men to superintend the operation of the mechanical equipment.

Pneumatic cleaning devices, or air tables, are applied to the small fractions (less than 3/8 inches). In these devices, currents of air flow upward through a perforated bottom plate over which a layer of coal passes. The extreme fines are entrapped in the air and must be recaptured by cyclones and bag filters for return without quality improvement. As the coal reaches the end of the tables, the bottom layer is heavy (high-ash) material, a center layer is medium-weight coal and bone (high-ash), and the top layer is coal (low-ash). The middle layer must be incorporated with the refuse (and rewashed) or with the coal.

Foreign materials are introduced into the coal during the mining process, the most common being roof bolts, ties, car wheels, timber, shot wires, and cutting bits. Foreign metals can be removed easily using magnets. Most wood fragments can be removed, although a few small pieces of wood cause no particular harm because they are combustible.



Air Table



Air Jig for coal cleaning

Froth flotation

Froth flotation is the most widely-used method for cleaning fines. Froth flotation cells utilize the difference in surface characteristics of coal and refuse to clean ultra fine coal. The coal-water mixture is conditioned with chemical reagents so that air bubbles will adhere only to the coal and float it to the top, while the refuse particles sink. Air is bubbled up through the slurry in the cell and clean coal is collected in the froth that forms at the top. Figure A5 shows an example of froth flotation. This type of cleaning is very complex and expensive and is principally for metallurgical coals. One of the commonest steps to improve the performance of a flotation unit is to separate the pyrite at an earlier stage using cyclones, spirals or tables.

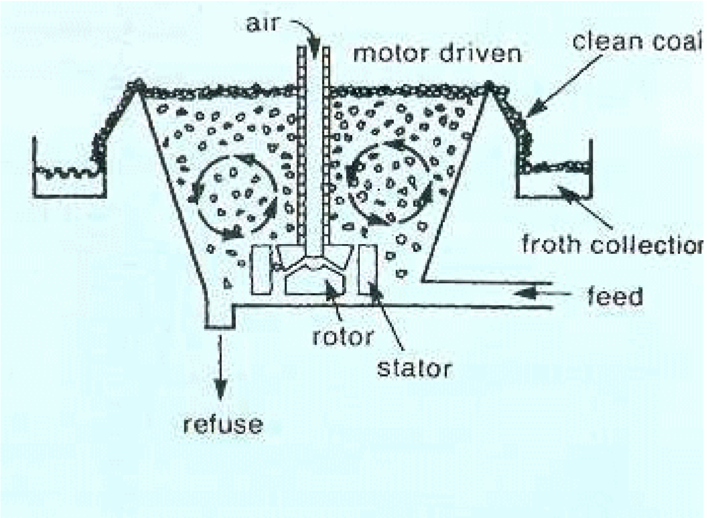


Fig. A5 Froth Floatation

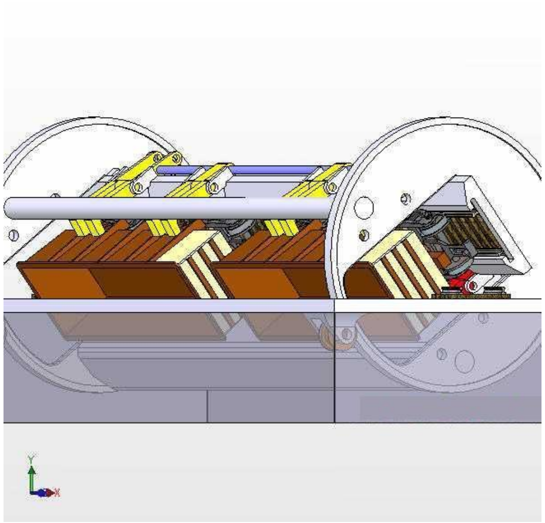
Froth flotation Coal Cleaner

Sulfur in coal occurs as sulfates, organic sulfur, and pyrites (sulfides of iron). The sulfates usually are present in small quantities and are not considered a problem. Organic sulfur is bound molecularly into the coal and is not removable by typical coal preparation processes. Pyrites generally are present in the form of modules or may be more intimately mixed with the coal. Coal preparation plants remove only a portion of the pyritic sulfur; therefore the degree of sulfur reduction depends on the percentage of pyrites in the coal, the degree to which this is intimately mixed with the coal, and the extent of coal preparation.

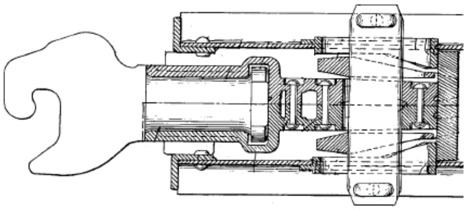
The free sulfur in the coal is subject to removal only by chemical treatment, which is not a coal preparation process, or by combustion. The reason that the pyrites can be partially removed in washing processes is that they are heavy enough to be removed with the ash. The processes can remove only 30 to 60 percent of the pyrites, however, because some pyrites are not broken free of the coal and are present in a given piece in a quantity too small to increase its weight enough to be rejected. www.envfor.nic.in/cpcb/newsletter/coal/cclean.html
https://kb.osu.edu/dspace/bitstream/1811/34798/1/OS_ENG_v12_i07_006.pdf

Once the coal is cleaned at the mine, how does it get to the Powerplant?

The coal is loaded onto a unit train at the loadout

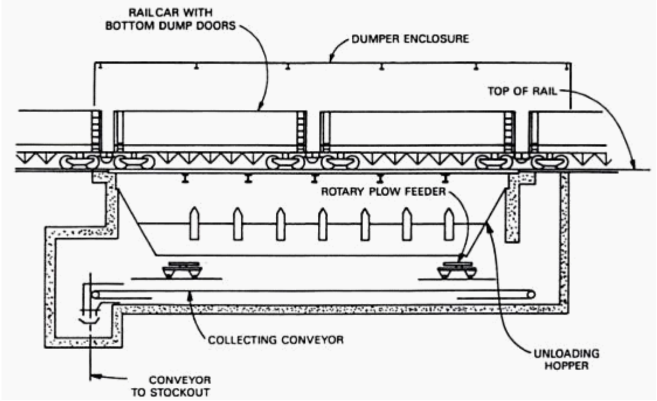


When it gets to the plant it is unloaded using a rotary car dumper that turns the coal car upside down while still attached to the train. It uses special couplings in order to do this



Rotary Car Dumper Coupler

One or more cars can be dumped at the same time from the rotary car dumper, depending upon design



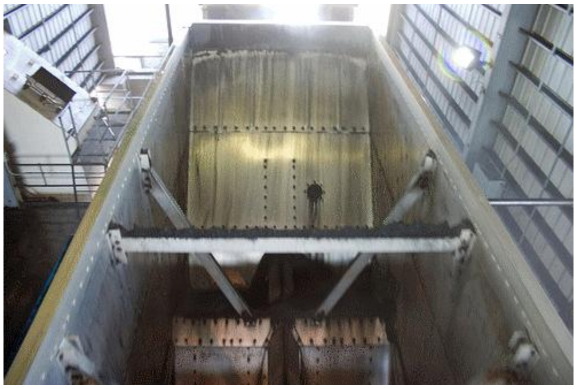
You can also unload the coal with a bottom dumping coal car

1.

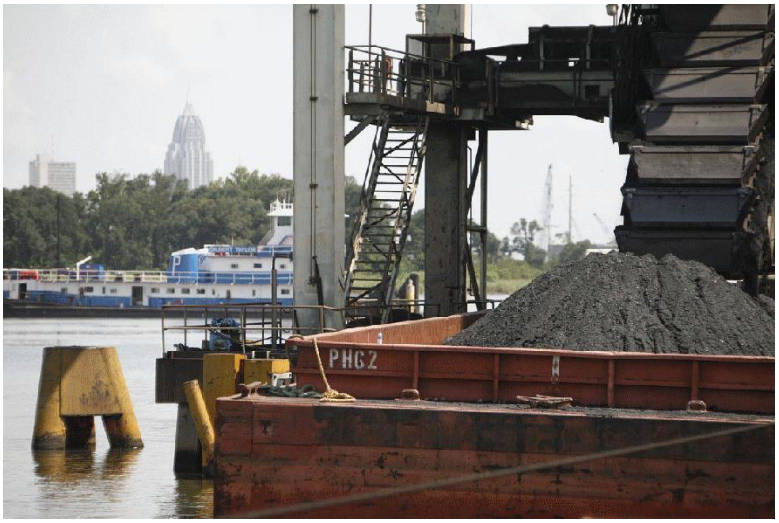
2.

3.

4.

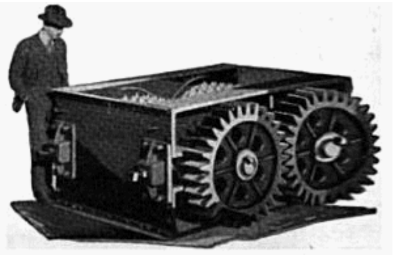


5. The first 5 photos show a Rail Car with Bottom Dumping in sequence as it unloads coal through the grizzly bars into the hopper feeding a crusher underneath

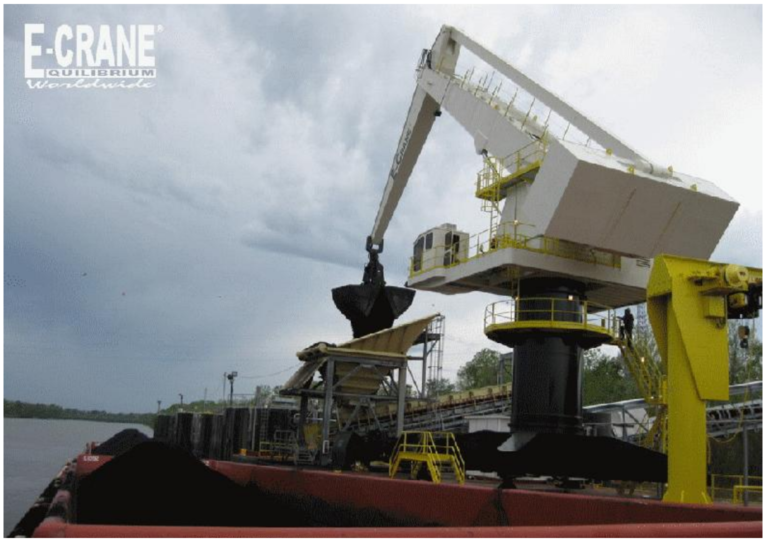


Rotary buckets on the right dig into a coal barge on the river in order to unload it

Grizzly Bars prevent personnel from falling through to the optional double roll crusher



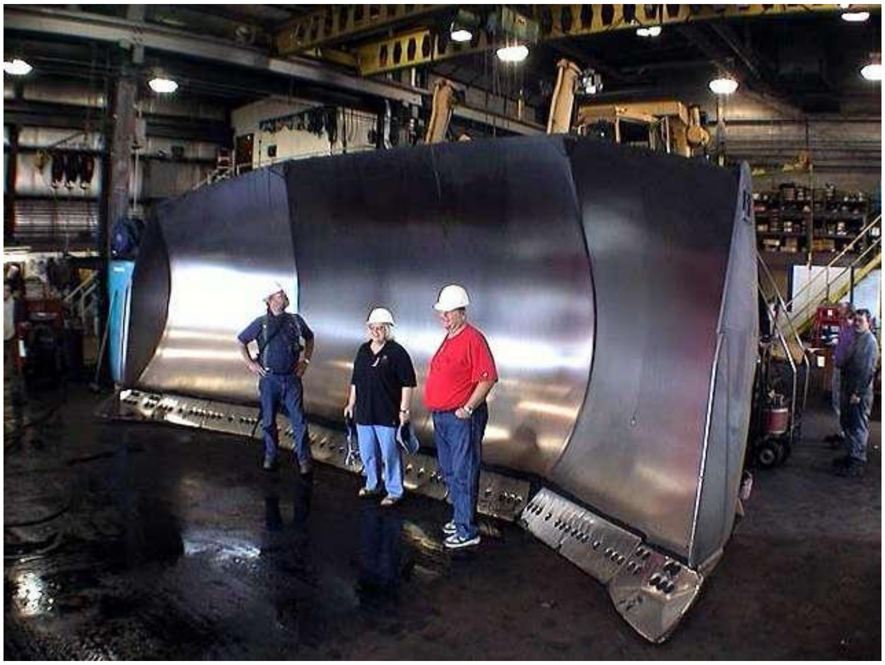
Potential victim of the double roll crusher weighs his options



E-crane uses a clamshell bucket on a swivel with a counterweight to unload the barge

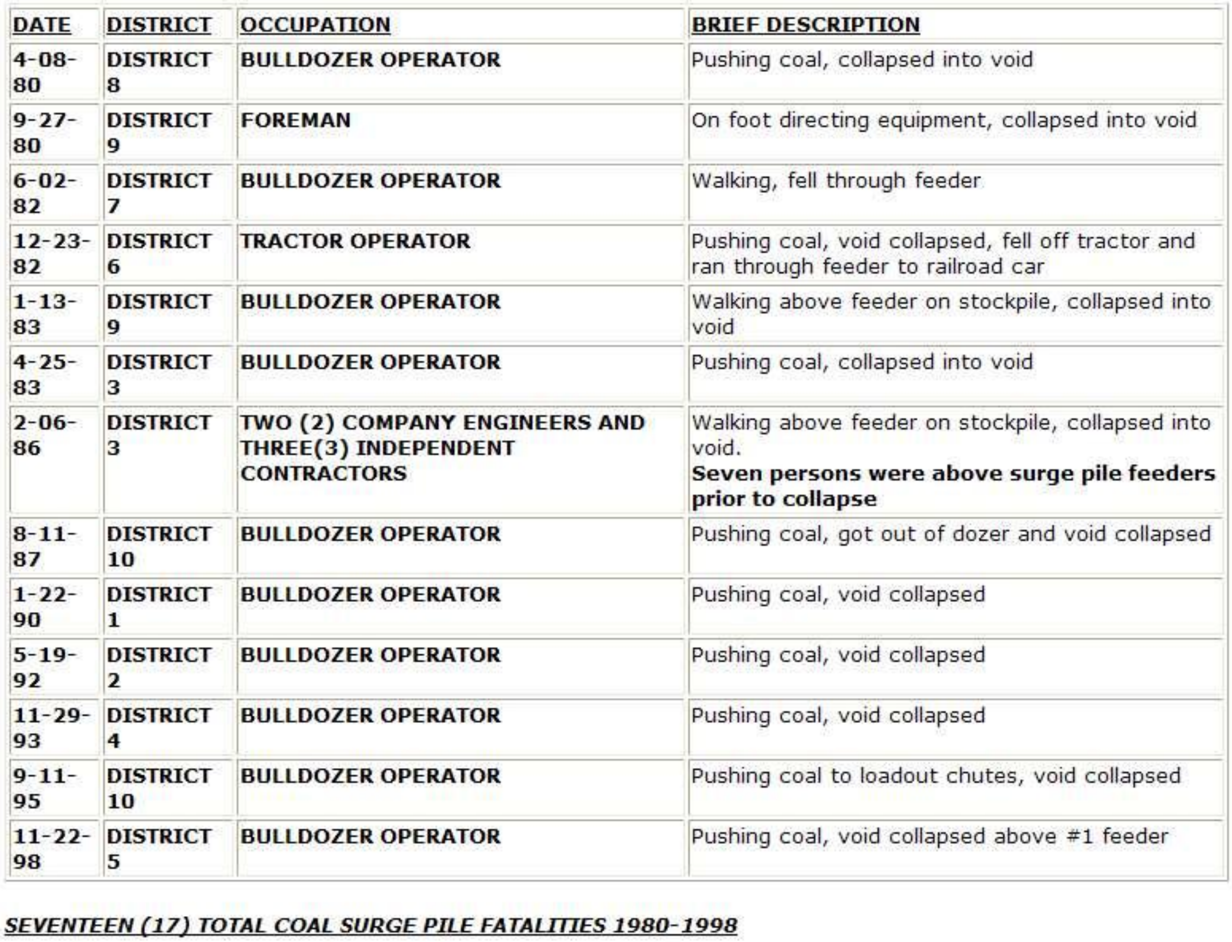
How is coal handled on the coal pile at the Powerplant?
In order to compact the coal, bulldozers, road graders, and earth movers push the coal around and pack the coal by running over it. Since coal is less dense than rock or dirt, a larger front blade can be used than on a normal bulldozer.

An earth mover and road grader work the coal pile.



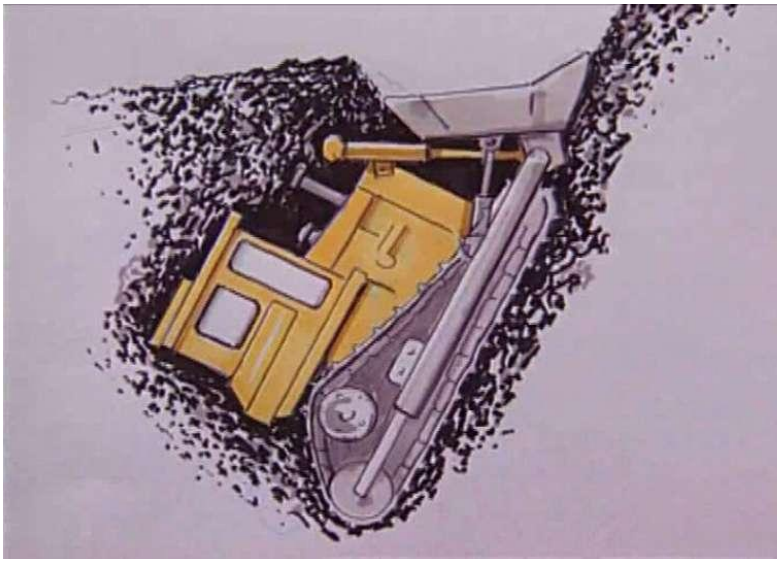
Bulldozer blade for coal

What are surge piles and draw holes and what are the dangers involved?
The coal pile over the rotary plow or vibratory drawdown hoppers is called a surge pile. The bulldozer pushes the coal toward the draw hole to keep the coal flowing on the reclaim tunnel to the powerhouse bunkers. As the coal is drawn down it can create a void in the pile and the bulldozer falls into the void and suffocates the driver. They reinforce the windows now and have air tanks in the bulldozer cab to help prevent surge pile deaths.

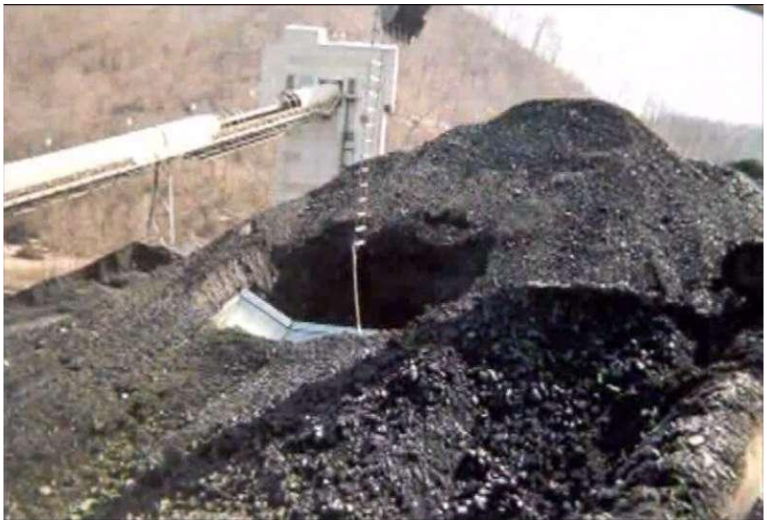


DATE	DISTRICT	OCCUPATION	BRIEF DESCRIPTION
4-08-80	**DISTRICT 8**	**BULLDOZER OPERATOR**	Pushing coal, collapsed into void
9-27-80	**DISTRICT 9**	**FOREMAN**	On foot directing equipment, collapsed into void
6-02-82	**DISTRICT 7**	**BULLDOZER OPERATOR**	Walking, fell through feeder
12-23-82	**DISTRICT 6**	**TRACTOR OPERATOR**	Pushing coal, void collapsed, fell off tractor and ran through feeder to railroad car
1-13-83	**DISTRICT 9**	**BULLDOZER OPERATOR**	Walking above feeder on stockpile, collapsed into void
4-25-83	**DISTRICT 3**	**BULLDOZER OPERATOR**	Pushing coal, collapsed into void
2-06-86	**DISTRICT 3**	**TWO (2) COMPANY ENGINEERS AND THREE(3) INDEPENDENT CONTRACTORS**	Walking above feeder on stockpile, collapsed into void. **Seven persons were above surge pile feeders prior to collapse**
8-11-87	**DISTRICT 10**	**BULLDOZER OPERATOR**	Pushing coal, got out of dozer and void collapsed
1-22-90	**DISTRICT 1**	**BULLDOZER OPERATOR**	Pushing coal, void collapsed
5-19-92	**DISTRICT 2**	**BULLDOZER OPERATOR**	Pushing coal, void collapsed
11-29-93	**DISTRICT 4**	**BULLDOZER OPERATOR**	Pushing coal, void collapsed
9-11-95	**DISTRICT 10**	**BULLDOZER OPERATOR**	Pushing coal to loadout chutes, void collapsed
11-22-98	**DISTRICT 5**	**BULLDOZER OPERATOR**	Pushing coal, void collapsed above #1 feeder

SEVENTEEN (17) TOTAL COAL SURGE PILE FATALITIES 1980-1998

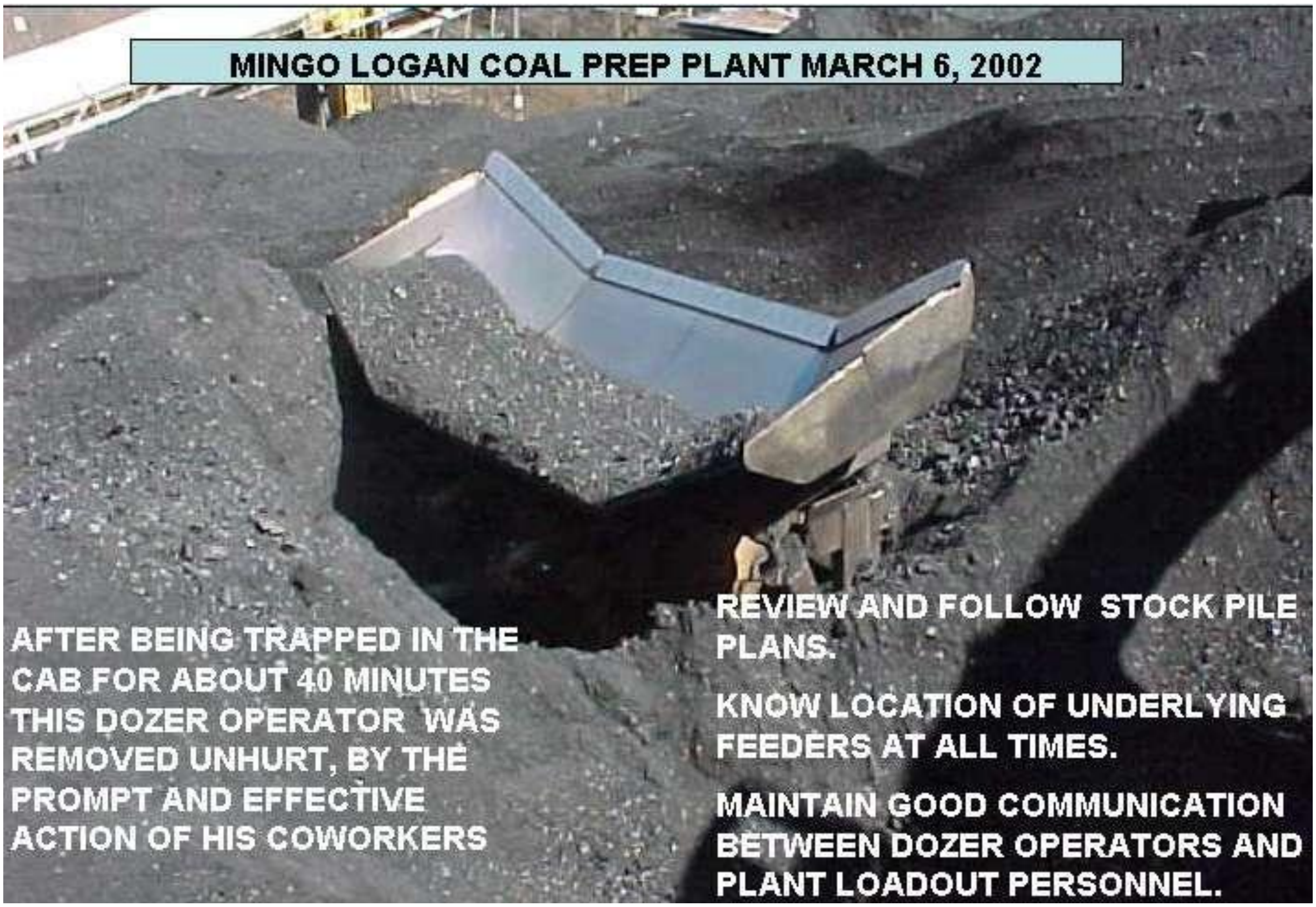


The bulldozer falls into the draw hole and is instantly buried



Bulldozer buried in surge pile due to void caused by rotary plow drawing coal from the bottom.

Bulldozer Operator is successfully rescued from the draw hole.



MINGO LOGAN COAL PREP PLANT MARCH 6, 2002

AFTER BEING TRAPPED IN THE CAB FOR ABOUT 40 MINUTES THIS DOZER OPERATOR WAS REMOVED UNHURT, BY THE PROMPT AND EFFECTIVE ACTION OF HIS COWORKERS

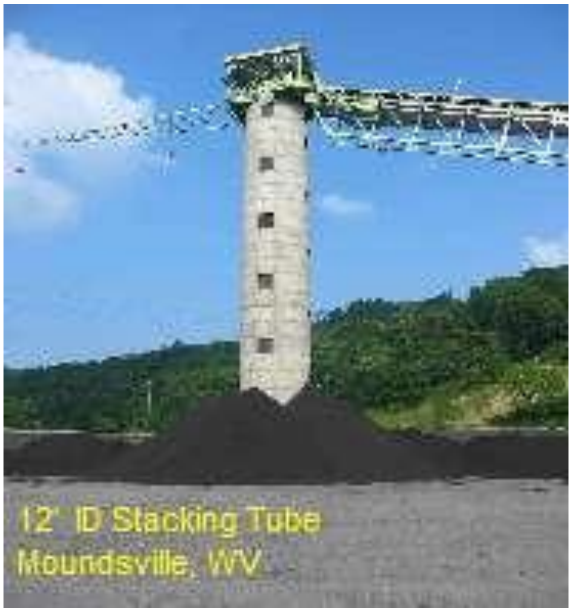
REVIEW AND FOLLOW STOCK PILE PLANS.

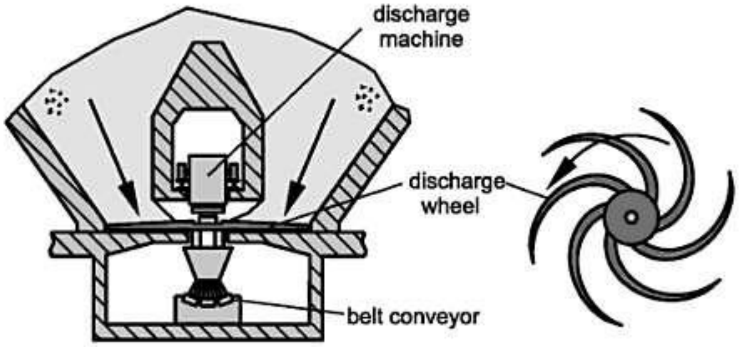
KNOW LOCATION OF UNDERLYING FEEDERS AT ALL TIMES.

MAINTAIN GOOD COMMUNICATION BETWEEN DOZER OPERATORS AND PLANT LOADOUT PERSONNEL.

What is a stacking tube and lowering well?

A stacking tube is a concrete coal silo with windows on opposite sides of the silo. The windows can have top hinged swinging doors but that is optional. A lowering well usually sits at the bottom of the stacking tube. It has a rotary plow reclaimer directly underneath the silo and a conical reclaim pit surrounds the base of the silo. As coal enters the top of the silo, the coal drops to the rotary plow which determines how much coal is dropped onto a reclaim conveyor running in a reclaim tunnel underneath the coalyard where the stacking tubes are located.

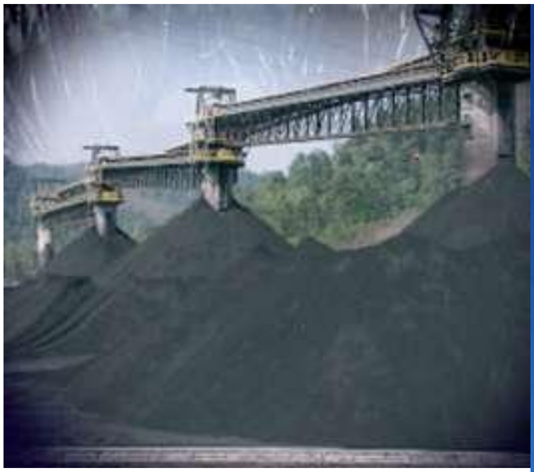




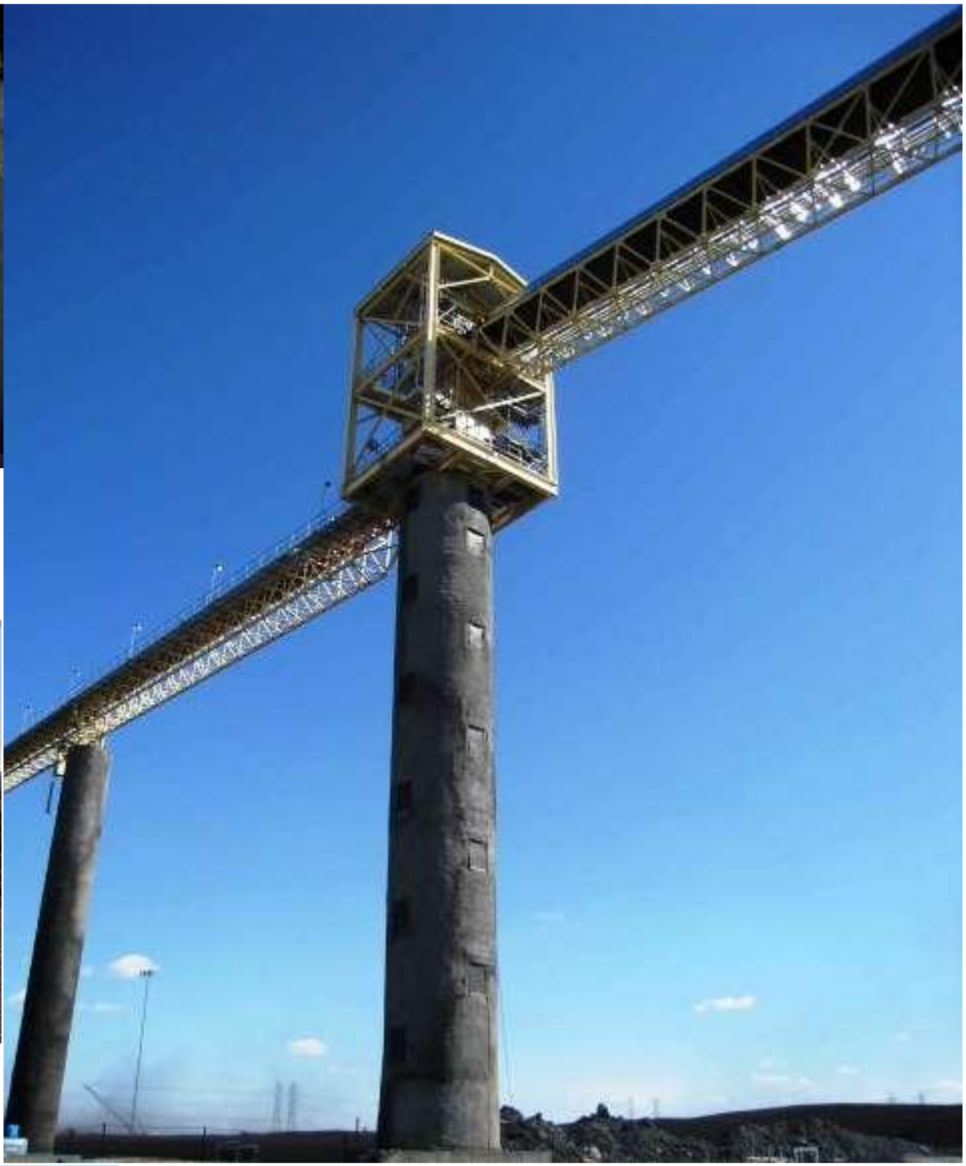
The Rotary Plow reclaimer sits at the bottom of a stacking well or at the bottom of a coal pile. Rotation of the horizontal spiral arms pull the coal into openings where it drops down a chute and onto a belt conveyor. For clarity the discharge wheel is shown in a vertical position in the diagram but it lays flat in operation and turns according to an adjustable speed motor above it sitting under a cone shaped cover in this example.

The bottom chute of the rotary plow over the conveyor in the reclaim tunnel.

An overhead horizontal conveyor usually connects 2 or more stacking tubes. As the coal fills the stacking tubes, it spills out the windows to form piles around the stacking tubes. A bulldozer is then used to push the coal into the conical pits surrounding the stacking tubes.



Stacking tubes with horizontal conveyors connecting the stacking tubes.



Stacking tubes showing the windows that the coal comes out as the coal fills the tube at that level. Eventually a pile of coal will surround the stacking tube.

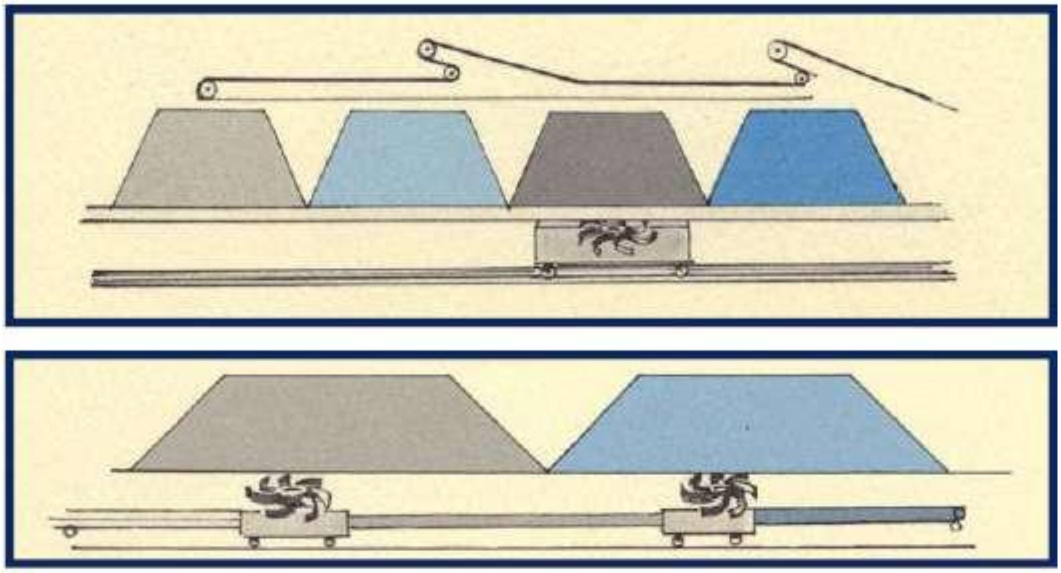
Stacking tube stockpiles at Toms Fork Loadout

Stacking tubes and connecting conveyors

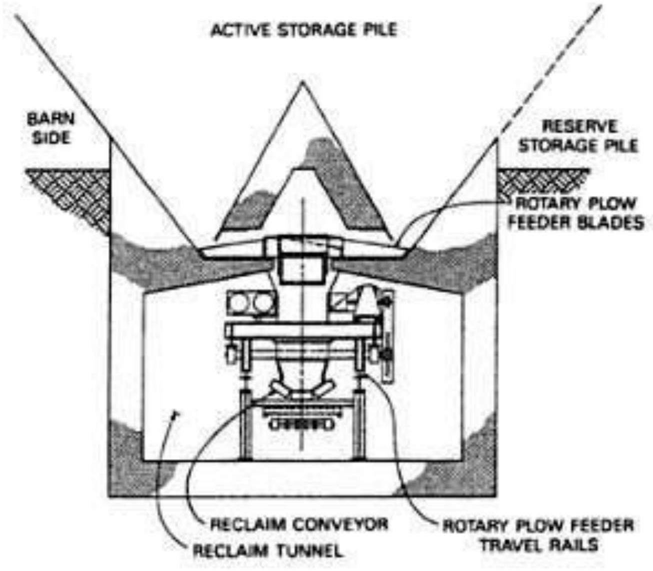
Four stacking tubes in a row with overhead conveyors connecting them

How is coal reclaimed from coal piles?

The same rotary plows that are used under stacking tubes are also used under coal piles.



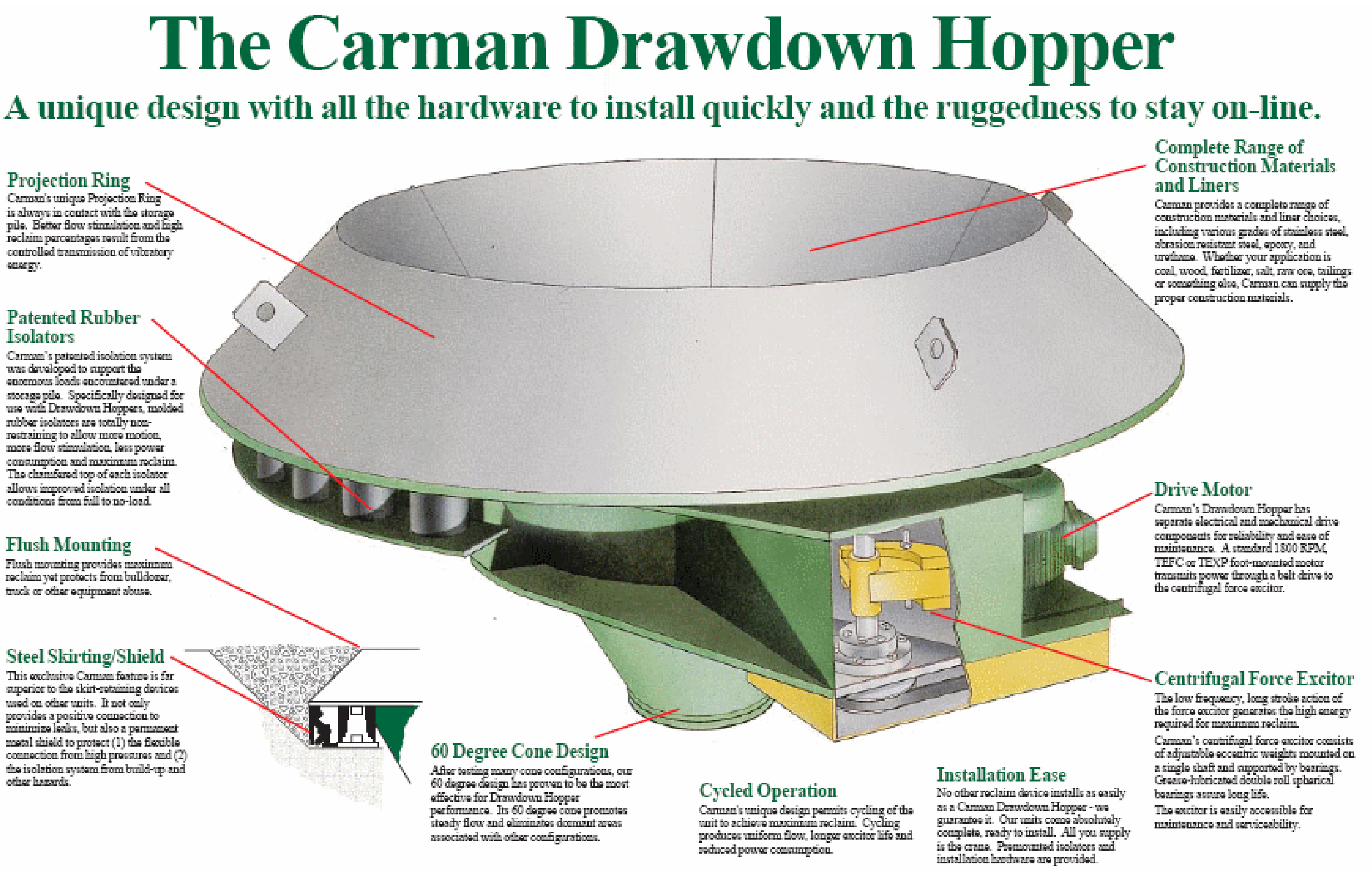
This drawing shows how rotary plows can be used to reclaim coal from different piles or blend different coals. The top drawing shows a belt conveyor with traveling trippers to drop different types of coal from different piles. The bottom drawing shows two rotary plows under different types of coal. A Power Plant that uses 70% Powder River Basin Coal and 30% Eastern coal would have the Powder river basin plow running at 70% speed and the Eastern plow running at 30% speed. The coal would fall on the conveyor in that proportion and be mixed on the belt on its way to the bunker in the powerhouse.



Reclaim system with rotary plow feeder.

The rotary feeders in the pictures on this page have the motor suspended underneath the rotary plow.

Vibrating feeders are also used to reclaim coal from the coal pile.



The Carman Drawdown Hopper

A unique design with all the hardware to install quickly and the ruggedness to stay on-line.

Projection Ring
Carman's unique Projection Ring is always in contact with the storage pile. Better flow stimulation and high reclaim percentages result from the controlled transmission of vibratory energy.

Patented Rubber Isolators
Carman's patented isolation system was developed to support the enormous loads encountered under a storage pile. Specifically designed for use with Drawdown Hoppers, molded rubber isolators are totally non-restraining to allow more motion, more flow stimulation, less power consumption and maximum reclaim. The chamfered top of each isolator allows improved isolation under all conditions from full to no-load.

Flush Mounting
Flush mounting provides maximum reclaim yet protects from bulldozer, truck or other equipment abuse.

Steel Skirting/Shield
This exclusive Carman feature is far superior to the skirt-retaining devices used on other units. It not only provides a positive connection to minimize leaks, but also a permanent metal shield to protect (1) the flexible connection from high pressures and (2) the isolation system from build-up and other hazards.

60 Degree Cone Design
After testing many cone configurations, our 60 degree design has proven to be the most effective for Drawdown Hopper performance. Its 60 degree cone promotes steady flow and eliminates dormant areas associated with other configurations.

Cycled Operation
Carman's unique design permits cycling of the unit to achieve maximum reclaim. Cycling produces uniform flow, longer excitor life and reduced power consumption.

Installation Ease
No other reclaim device installs as easily as a Carman Drawdown Hopper - we guarantee it. Our units come absolutely complete, ready to install. All you supply is the crane. Premounted isolators and installation hardware are provided.

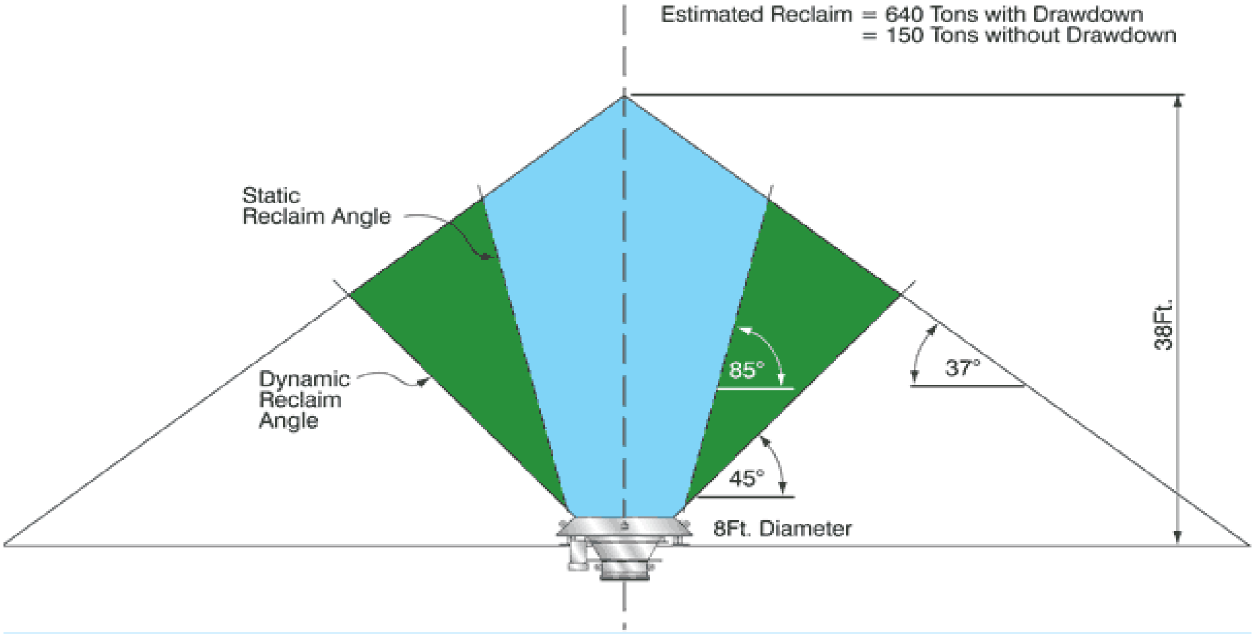
Complete Range of Construction Materials and Liners
Carman provides a complete range of construction materials and liner choices, including various grades of stainless steel, abrasion resistant steel, epoxy, and urethane. Whether your application is coal, wood, fertilizer, salt, raw ore, tailings or something else, Carman can supply the proper construction materials.

Drive Motor
Carman's Drawdown Hopper has separate electrical and mechanical drive components for reliability and ease of maintenance. A standard 1800 RPM, TEFC or TEXP foot-mounted motor transmits power through a belt drive to the centrifugal force excitor.

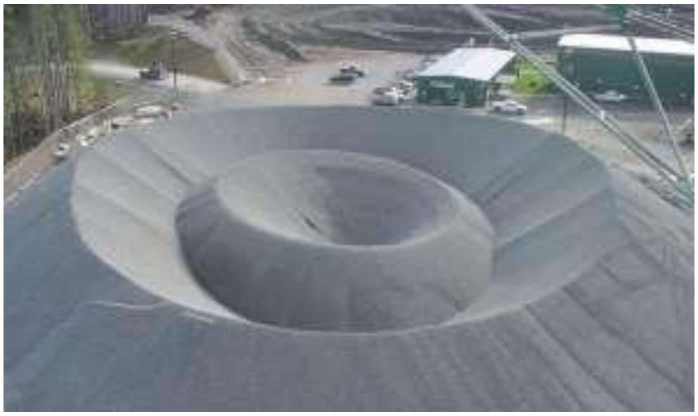
Centrifugal Force Excitor
The low frequency, long stroke action of the force excitor generates the high energy required for maximum reclaim.

Carman's centrifugal force excitor consists of adjustable eccentric weights mounted on a single shaft and supported by bearings. Grease-lubricated double roll spherical bearings assure long life.

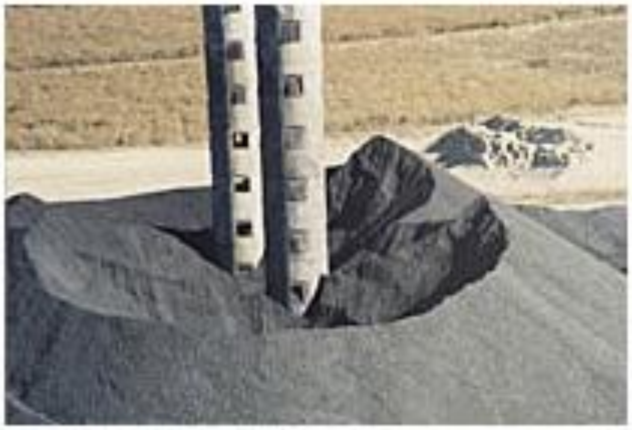
The excitor is easily accessible for maintenance and serviceability.


Estimated Reclaim = 640 Tons with Drawdown
= 150 Tons without Drawdown
Static
Reclaim Angle
Dynamic
Reclaim
Angle
85°
37°
45°
38Ft.
8Ft. Diameter

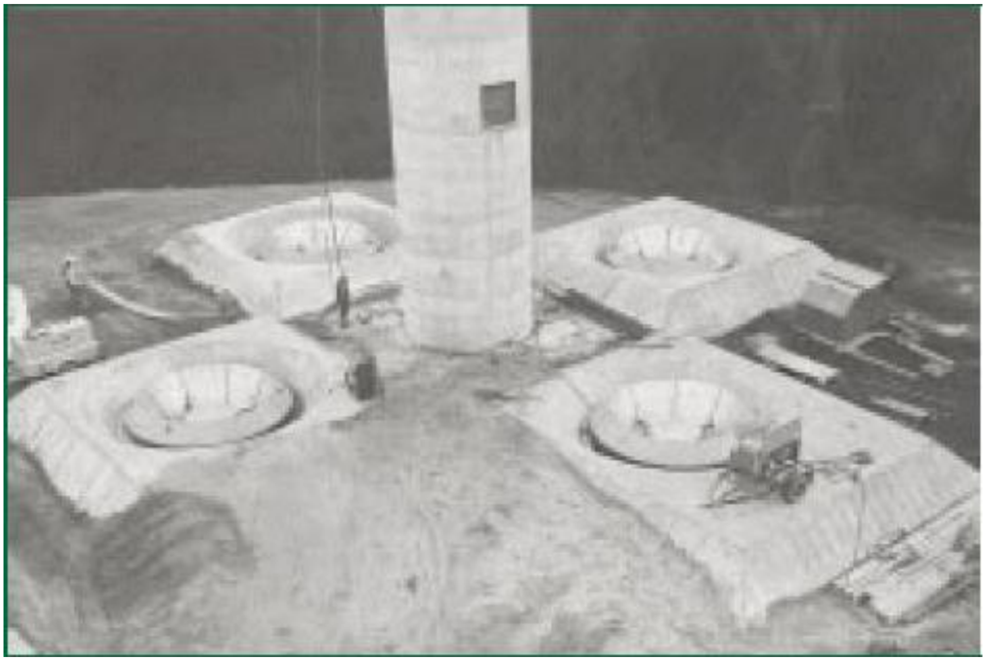
This drawing shows a coal pile with the angles that will be formed when the coal is piled and the angles formed as the coal is reclaimed below the coal pile.



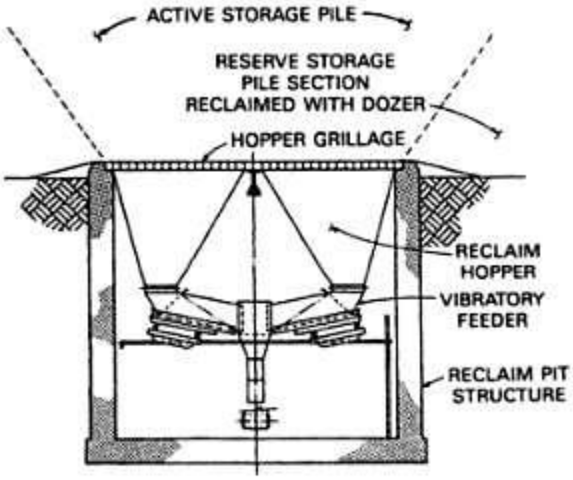
The coal pile is collapsing from the top as the coal is drawn off the bottom.



The coal pile is collapsing at the stacking tube into the lowering wells.

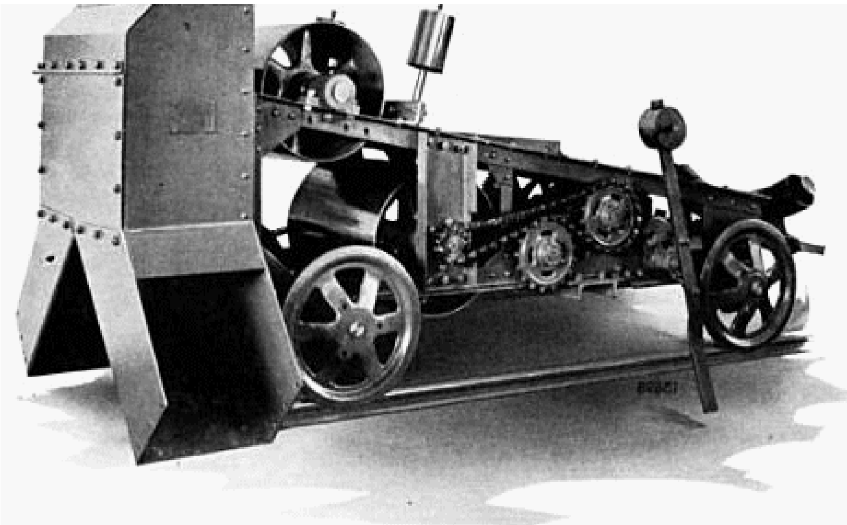


This picture shows four drawdown hoppers surrounding a stacking tube.

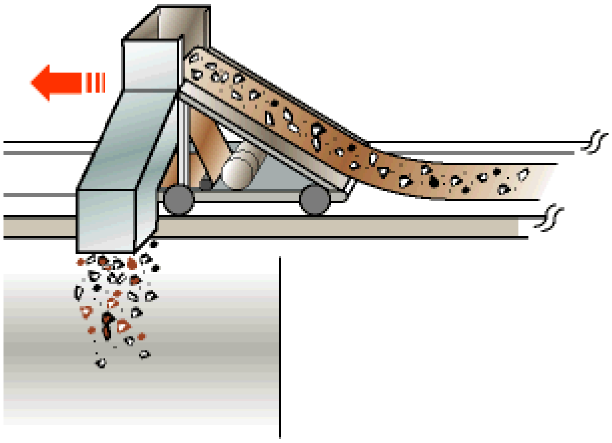


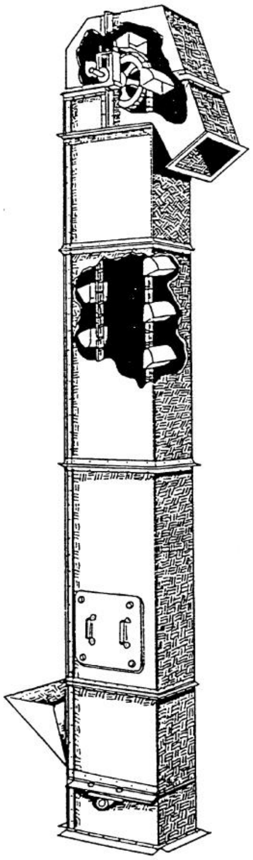
The vibratory feeder sits underneath the level of the surrounding ground.

Hoppers installed over reclaim tunnels with stacking conveyors overhead.



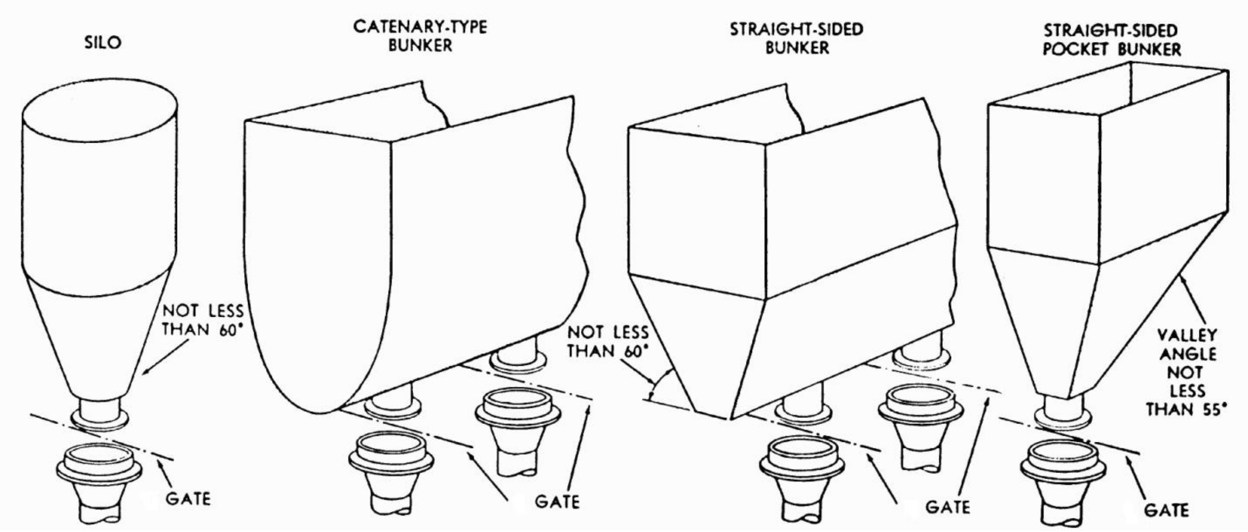
Traveling Tripper drops coal from a conveyor into the coal silo

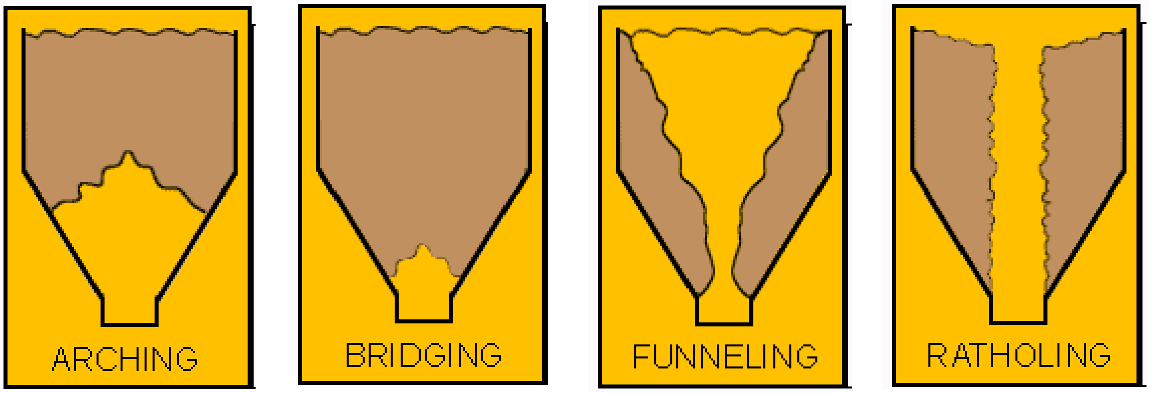




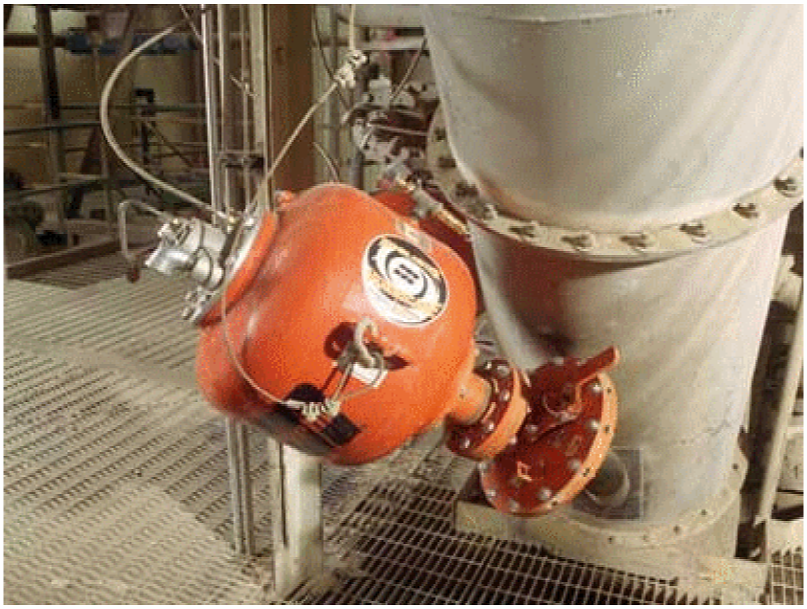
Bucket elevators move coal in a vertical direction

Different types of coal bunkers





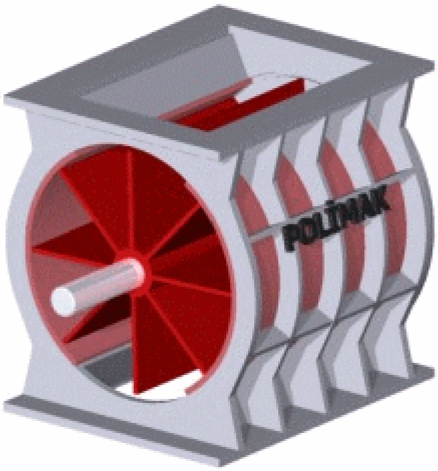
Different types of problems encountered in coal bunkers. Pneumatic cannons and vibrators are used to solve these problems



BIG BLASTER® Air Cannons have been used around the world to prevent buildups and improve material flow. Martin Engineering is the leader in the application of air cannon technology to over come bottlenecks and boost flow through high capacity vessels.

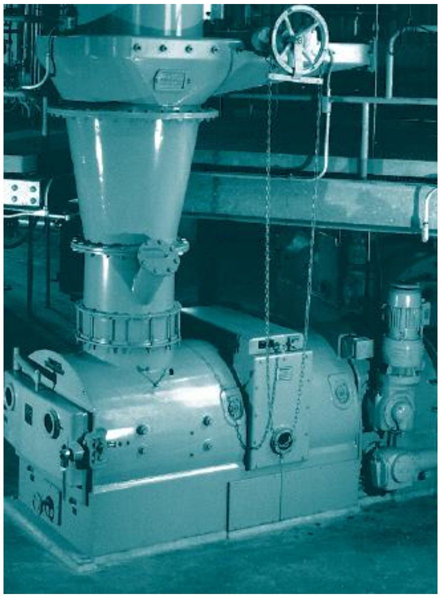
Vibrators can also be used to get the coal flowing.

Rotary Feeder

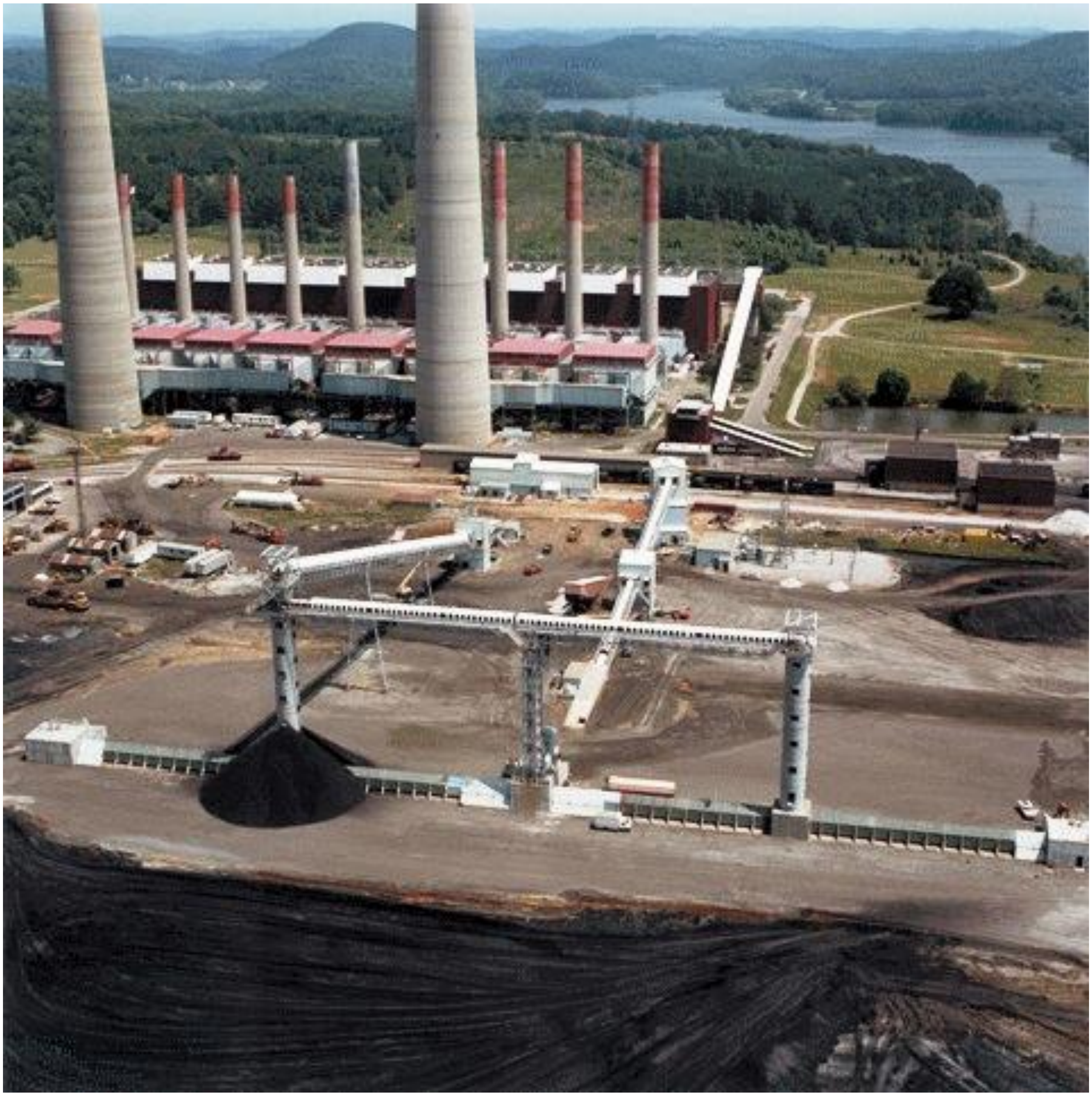


Internal view of a rotary feeder

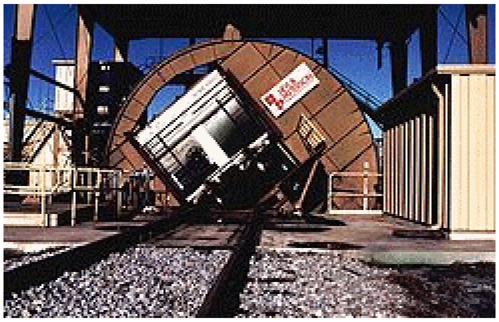
Stock Gravimetric Feeder



Stock Volumetric Feeder



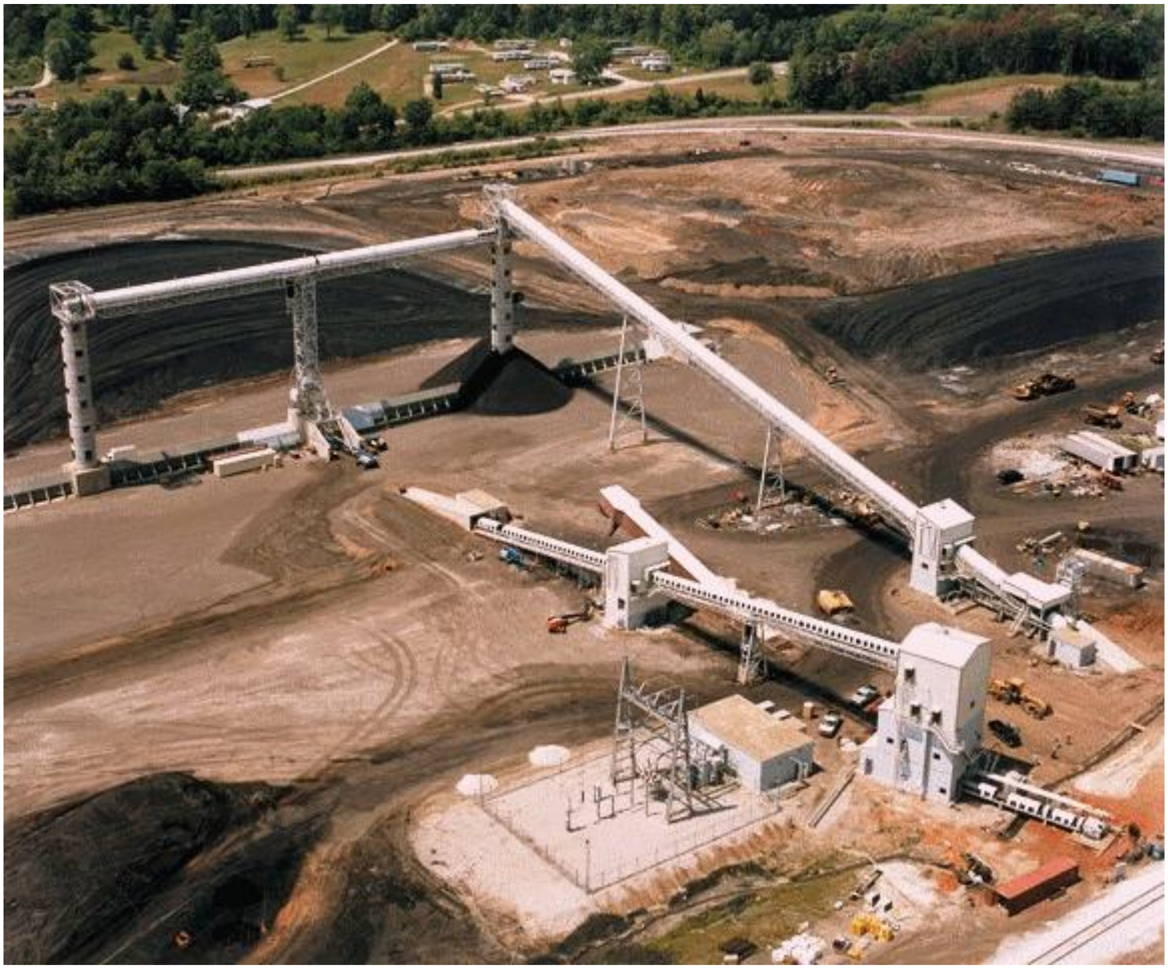
The Kingston coal handling facility received coal by train that was unloaded at a rotary car dumper on ladder tracks. To modernize and increase the unloading system capacity a rapid discharge bottom dump unloading system was furnished with a capacity of 4,400 tons per hour.



Rotary Car Dumper

Modern Rail Car Bottom Dumper

To stock out and store regional coals for blending the fixed stockout conveyor was replaced by a stacking conveyor and transfer conveyor to two stacking tubes. There are provisions for a third stacking tube and the transfer conveyor would be extended and reversing. Each stacking tube provided for a 62,000-ton capacity segregated pile.



Reclaim for blending from the piles is by two variable capacity rotary plow feeders. The reclaim capacity was increased from 2,000 to 2,400 tons per hour. At the new crusher building two 1,200 tons per hour crushers processed the coal, and then transfer the coal to the existing dual plant supply conveyors. These conveyors were modified with new drives and increased belt speed for the increased capacity. The ancillary systems included fire protection, wet-dust suppression, as-received and as-blended sampling systems, and ventilation systems. The plant consumes about 14,000 tons of coal a day.

The active coal pile is normally defined as a three-day supply of coal at the maximum burn rate. If it is PRB coal it must be reclaimed on a first-in, first-out basis to avoid spontaneous combustion. When rotary plow feeders for reclaim are used, it could be a fully automated system with an active coal pile trench arrangement.

Begun in 1951, Kingston was the largest coal-fired power plant in the world when completed in 1955. It was built primarily to provide electricity to atomic energy installations at nearby Oak Ridge.

The plant has nine generating units: units 1–4, rated at 175 megawatts each (launched into service in 1954), and units 5–9, rated at 200 megawatts each (launched in 1955). It produces about ten billion kilowatt hours of electricity from some five million tons of coal each year. That is enough electricity to supply more than 700,000 homes.

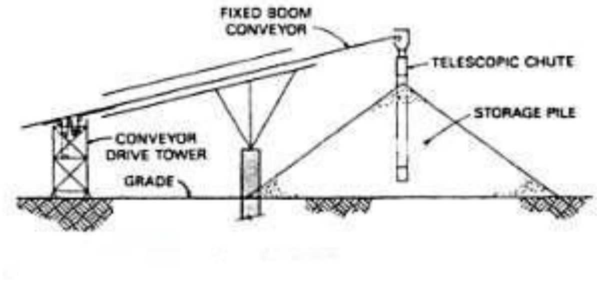
In 1976, its original stacks were taken out of service (though left standing) and replaced by a pair of 1,000 foot tall chimneys, one for units 1–5 and one for units 6-9. By 2010, the Tennessee Valley Authority (the taxpayers) will have spent about $6 billion on emissions controls at its fossil-fuel plants to ensure that this power supply is generated as cleanly as possible, consistent with efficiency.

To reduce sulfur dioxide (SO_2) emissions, all nine units use a blend of low-sulfur coal. Scrubbers are being added to the units to further reduce SO_2. This project will be completed in fiscal year 2010 at a cost of about $500 million. To reduce nitrogen oxides (NO_X), all nine units operate with selective catalytic reduction systems, which reduce NO_X emissions by 90 percent.

On December 22, 2008, a retention pond wall collapsed at TVA's Kingston plant in Harriman, TN, releasing a combination of water and fly ash. 5.4 million cubic yards (1.09 billion gallons) of fly ash was released from the storage facility flooding 400 acres.

What are stackers and stacker/reclaimers?

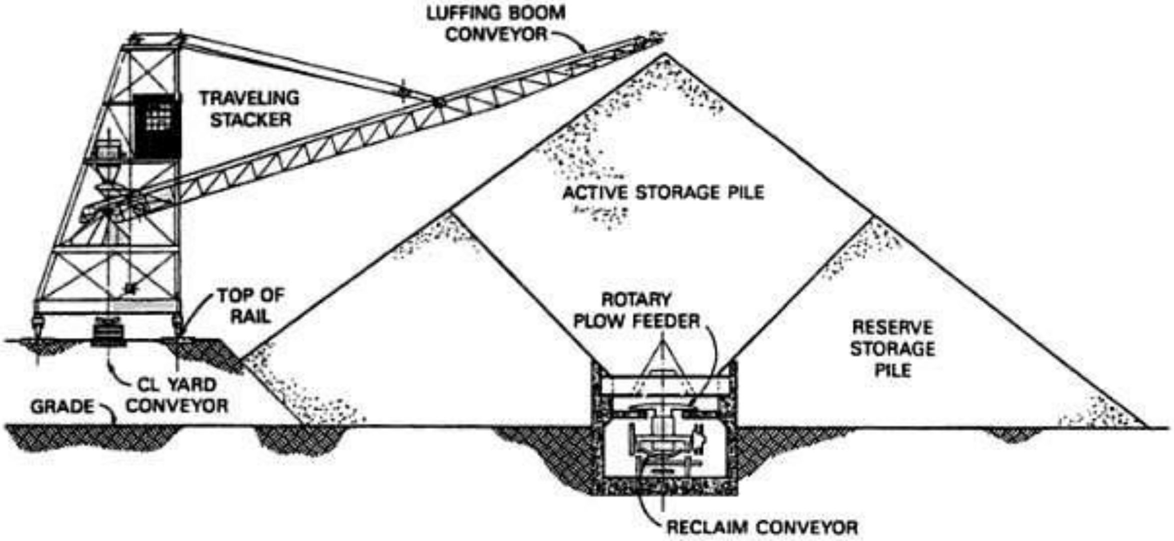
Stackers are types of equipment used to build coal piles. Stacker/reclaimers can also reclaim the coal from an existing coal pile. Stackers can have a fixed boom that forms a cone shaped pile.



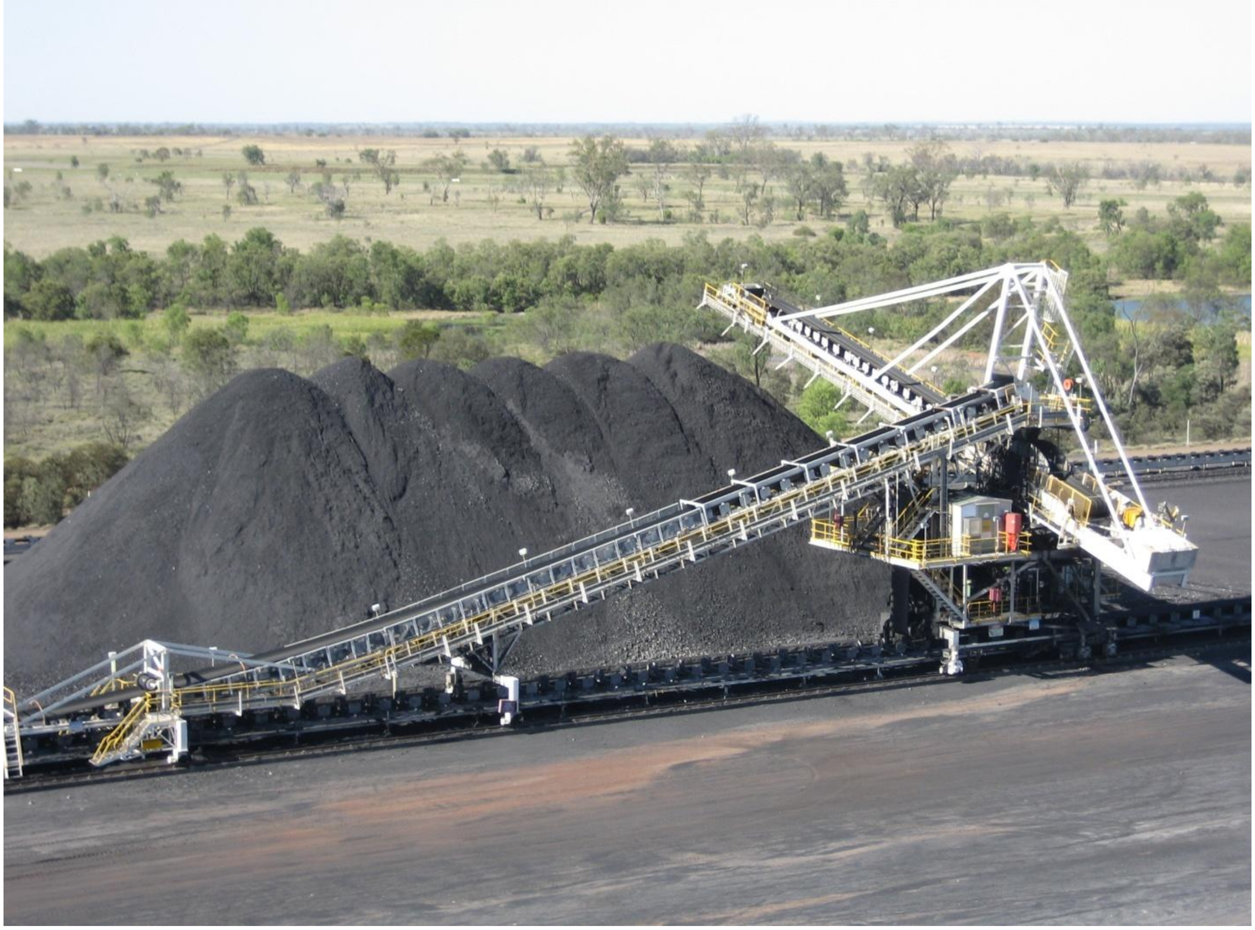
Fixed Boom Stacker

2800 t.p.h. Coal Stockout Conveyor

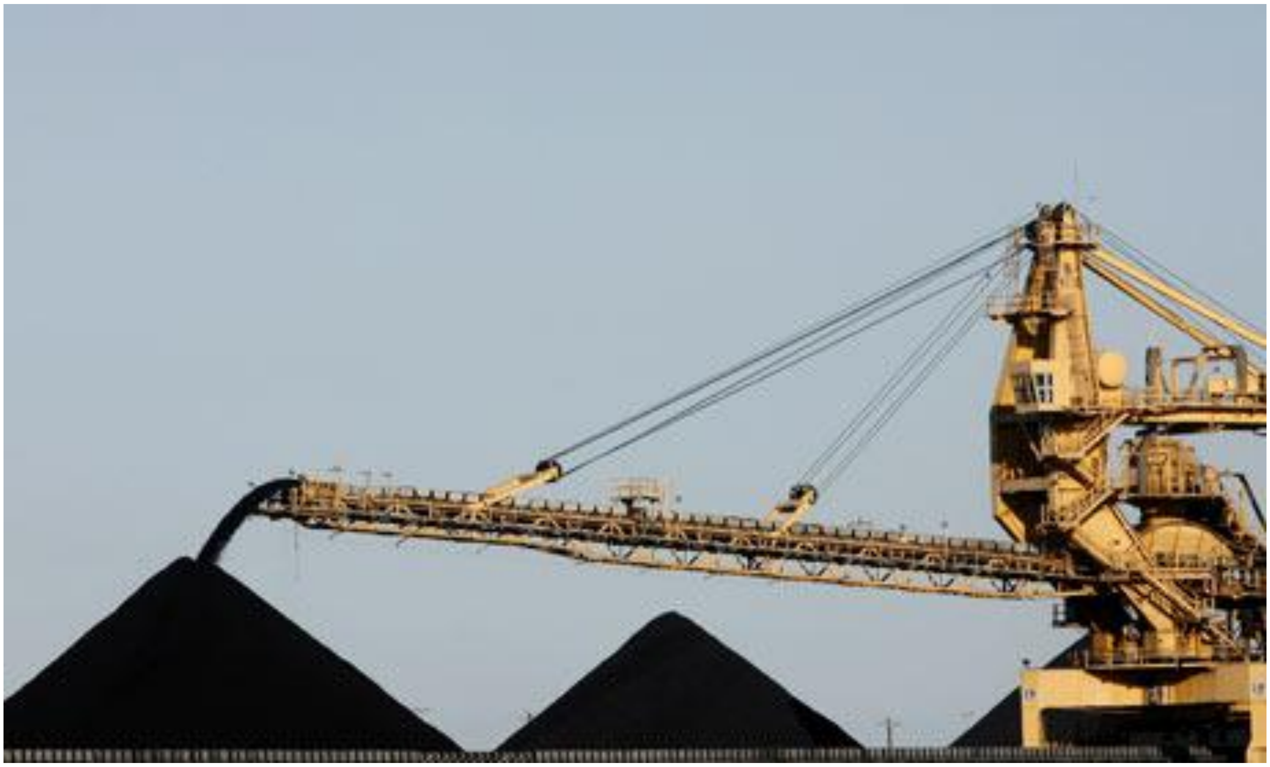
Fixed Boom Stacker



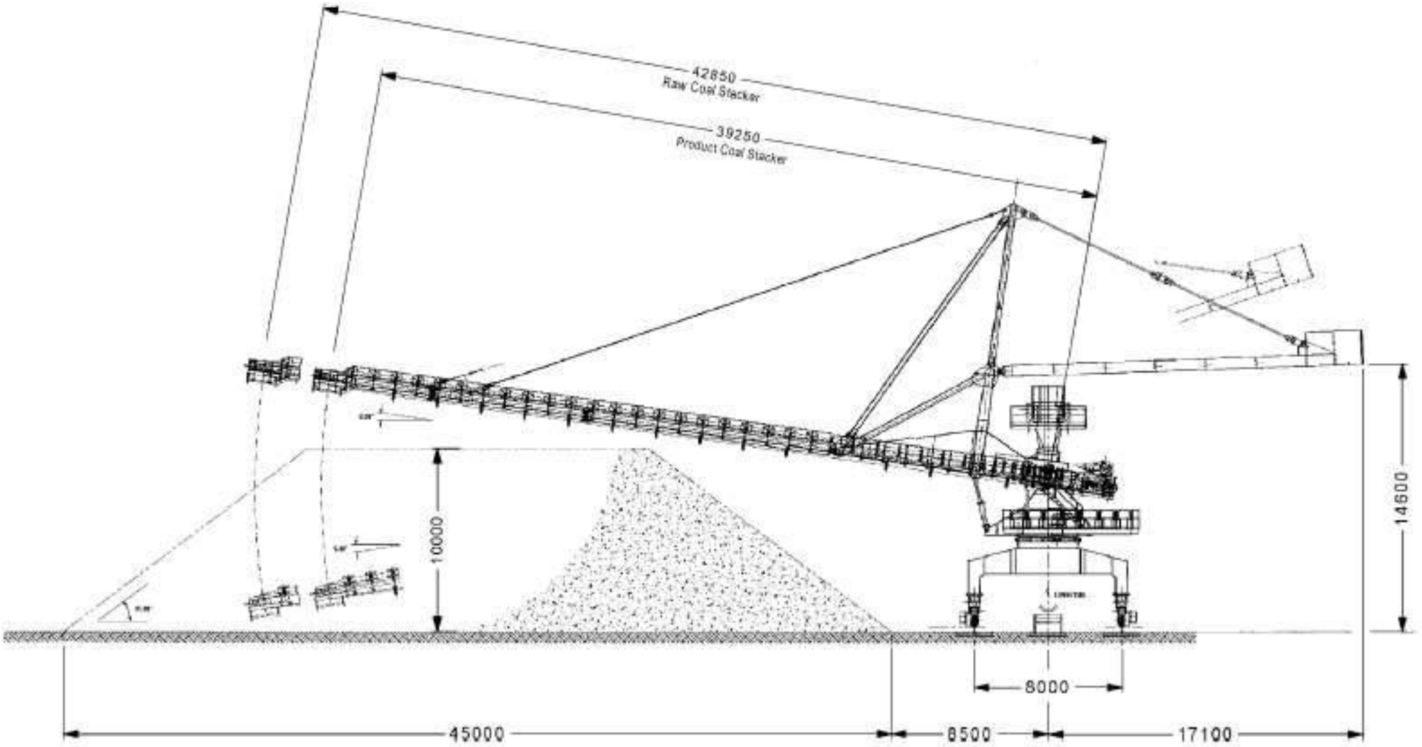
Traveling stacker on rails that can create a long triangular pile with rotary plow feeder underneath the coal pile.



A luffing stacker is one where the boom can up and down so that it minimizes dust creation while stockpiling coal. When it travels on rails, it builds a series of overlapping cones.



A Luffing and Slewing Stacker can move its boom back and forth as well as up and down.



Slewable Stacker As 1400 / 42,9 x 14,5

Stackers that are luffing and slewable can build coal piles by chevron stacking. Chevron stacking is when the stacker travels along the length of the stockpile adding layer upon layer of material.

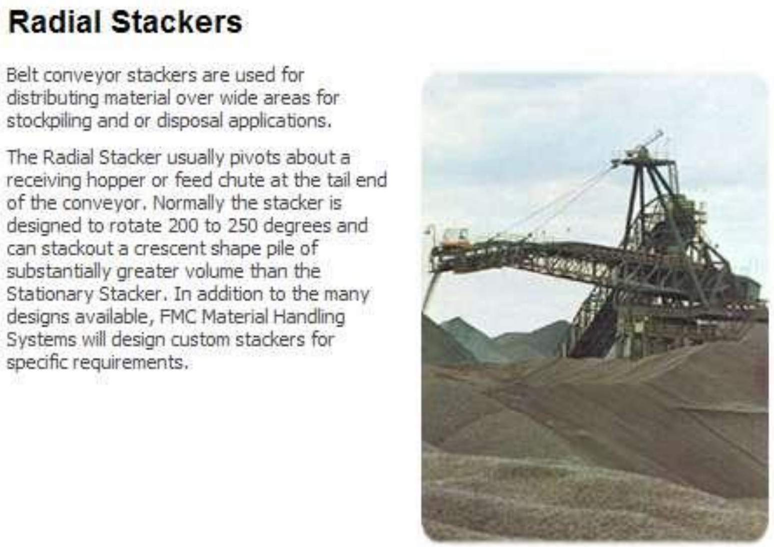
This stacker runs on straight rails and can build a chevron coal pile with sides that are angled with the natural angle of repose. The bulldozers and earth movers square off the top of the pile while compacting it.

What is a radial stacker?

A radial stacker can form a kidney shaped coal pile as the conveyor swings around a central pivot point.

The stackers are built for 24 hour operation. The night-time photo depicts a stacker in operation with coal discharging from the conveyor belt to form a radial stockpile.

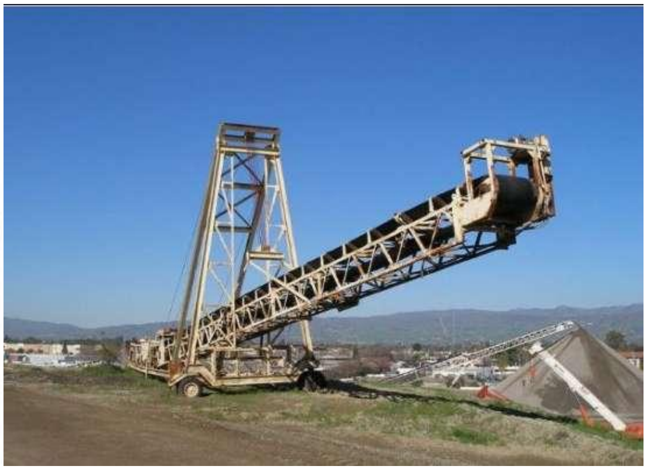
This shows one of the Sonoma stackers in operation. Coal moves along the in-feed conveyor belt onto the stacker and is then discharged onto the stockpile at the rate of 800 tonnes per hour.



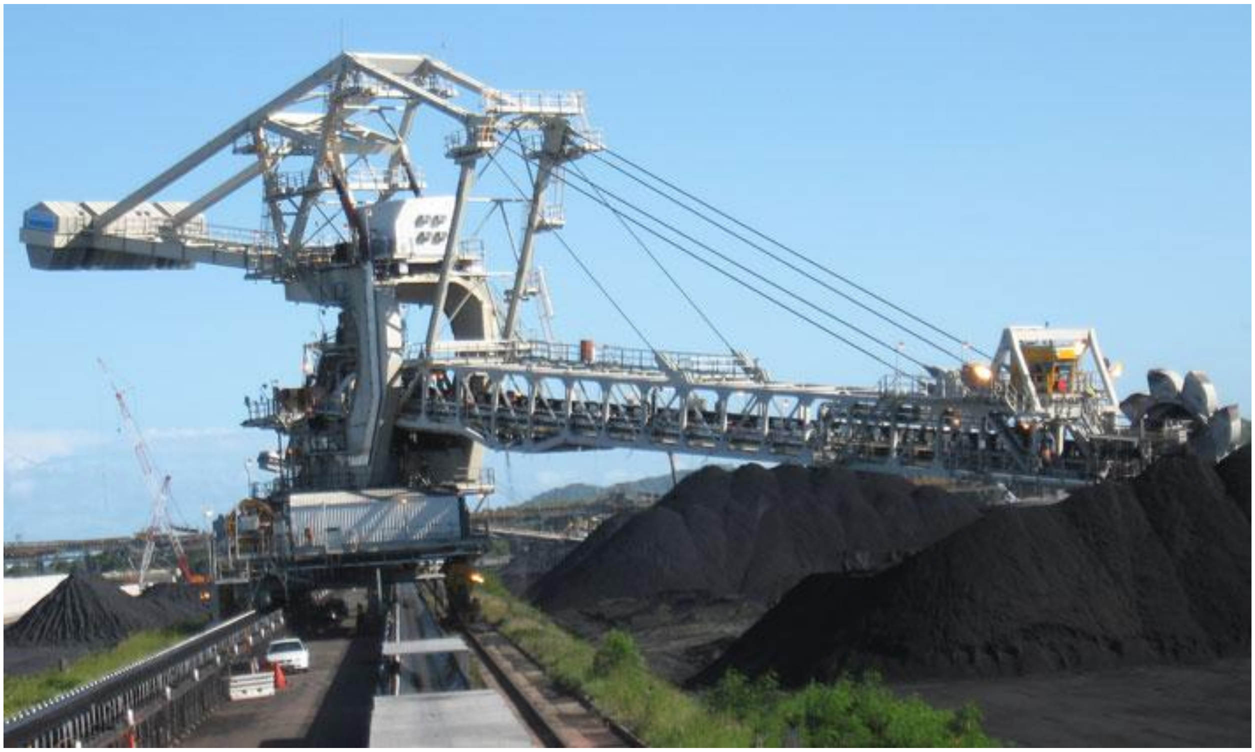
Radial Stackers

Belt conveyor stackers are used for distributing material over wide areas for stockpiling and or disposal applications.

The Radial Stacker usually pivots about a receiving hopper or feed chute at the tail end of the conveyor. Normally the stacker is designed to rotate 200 to 250 degrees and can stackout a crescent shape pile of substantially greater volume than the Stationary Stacker. In addition to the many designs available, FMC Material Handling Systems will design custom stackers for specific requirements.



Radial Stacker



A stacker/ reclaimer has a bucket wheel on the end of the conveyor so that it can use the buckets to load coal from the piles back onto the conveyor (now running backwards) and transports coal from the pile to the coal bunkers in the powerhouse. It is the most versatile of the track mounted stacker/reclaimers.

Explain how to get a good sampling of coal from the shipment for analysis.

A sample must represent the bulk of the coal from which it is taken. The items that should be most representative are ash and moisture content. The weight of the gross sample and the method of collecting and handling it depends upon the size of the coal, the moisture content, and the purpose for which the sample is collected. The weight of the sample may vary from 250 lb to 1000 lb. The larger the sample, the better the chances that it represents the bulk of the coal. The method of collecting the sample should be so chosen as to insure representative ash and moisture content. After the sample is collected, it must be handled in such a way that the moisture content does not change. If the coal is very wet, considerable loss of moisture may occur during the handling. It may be necessary to stabilize the moisture in the gross sample by air drying before crushing and quartering are undertaken. In such cases, the air-drying moisture loss must be determined. Collecting and handling the sample require care and ingenuity on the part of the sampler. The most difficult task is to sample a carload of run-of-mine coal. Usually, a large part of the fines sift to the bottom of the car. These fines contain more moisture than the lumps, and generally more ash. If the carload must be sampled, the weight of the gross sample should be about 1000 lb. A hole should be dug about 1/4 car length from each end of the car, and about half way down to the bottom, and the sample should be collected from these holes in such a way that they will contain the right proportion of fines and lumps. A carload of screening is easier to sample, because there is less chance for the finer particles to segregate. The best way to sample carloads, when the coal is dumped and moved by conveyers to storage bins or piles, is to collect the sample as the coal drops off the conveyer. Shovelfuls taken at equal intervals will give a fairly representative sample, and the weight of the sample can be reduced to 500 lbs., or even 250 lbs. During the collection of the sample, the coal should be placed in a can, which should be kept tightly covered between the periods of collection of individual shovelfuls to prevent the loss of moisture from the sample. On boiler tests with wet coal, made to show whether or not the guaranteed efficiency is obtained, a special procedure of collecting and handling the samples may be advisable; otherwise a moisture loss of 2 to 3% may occur, which would lower the calculated efficiency by the same amount. In such cases, it is advisable to collect a 25 lb to 50 lb lot at equal intervals of one to three hours, depending on the length of the tests.

These samples should be collected at the weighing apparatus, put in cloth bags, weighed immediately after collection, and then placed on shelves or racks in a room where they are to be subsequently reduced to the small laboratory sample. The bags should be weighed every six hours and the loss of moisture noted. The reduction in weight will gradually become smaller until, at the end of three days, the weight becomes constant and the moisture in the coal is in equilibrium with the room atmosphere. It is then safe to crush and reduce the sample by quartering to laboratory size. The crushing and quartering should be done on a steel plate and not on a dry concrete floor.

Blue Combustion Engineering, pages 2·1 and 2·2

Four other ways are:

1. Stopped belt cut

2. Full stream cut

3. Part stream cut

4. Stationary sampling

Don Pollock sampling clean coal from conveyor belt (1988)

After sampling the coal, it is put into bags and taken for analysis

Sampling coal

Reliable data on the physical and chemical characteristics of coal are required by power-plant operators. Hence, a sample must represent the bulk of the fuel from which it is taken. To design and implement a sampling program that will yield unbiased results, it is necessary to follow the applicable ASTM standards rigidly. The two that are of greatest concern to you: D2234 and D 2013. Note that, in powerplant work, the principles of good sampling generally are best satisfied by sampling from conveyors or chutes, rather than from storage piles, rail cars, barges, hoppers, etc.

Sampling systems used in industry often are relatively complex. For example, the first step in typical large system is to obtain a gross sample of coal from a conveyor or chute with a primary sampler. For a given accuracy, the quantity of material obtained by a single cut of the sampling instrument is increased with an increase in coal size and in expected ash and moisture content. Material selected by the primary sampler is transferred to a first-stage crusher, which reduces size while minimizing

1. the production of fines
2. volatile loss
3. moisture loss

The crushed coal is fed by a feeder to a second sampler. Sample rejects from this unit are collected and returned to the main coal handling system, while the selected material is transported to a secondary crusher, which reduces coal size further. A secondary feeder injects this coal into a tertiary sampler, which picks the material to be collected and shipped to the laboratory for analysis.

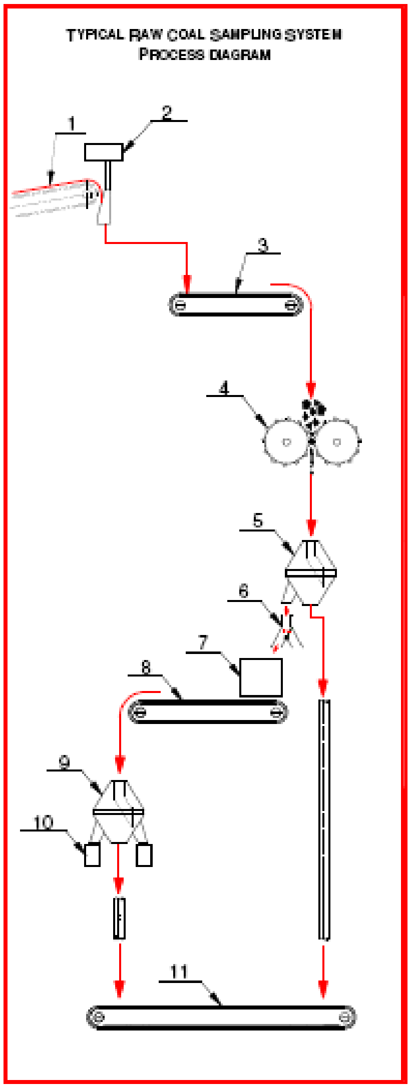


DIAGRAM LEGEND:

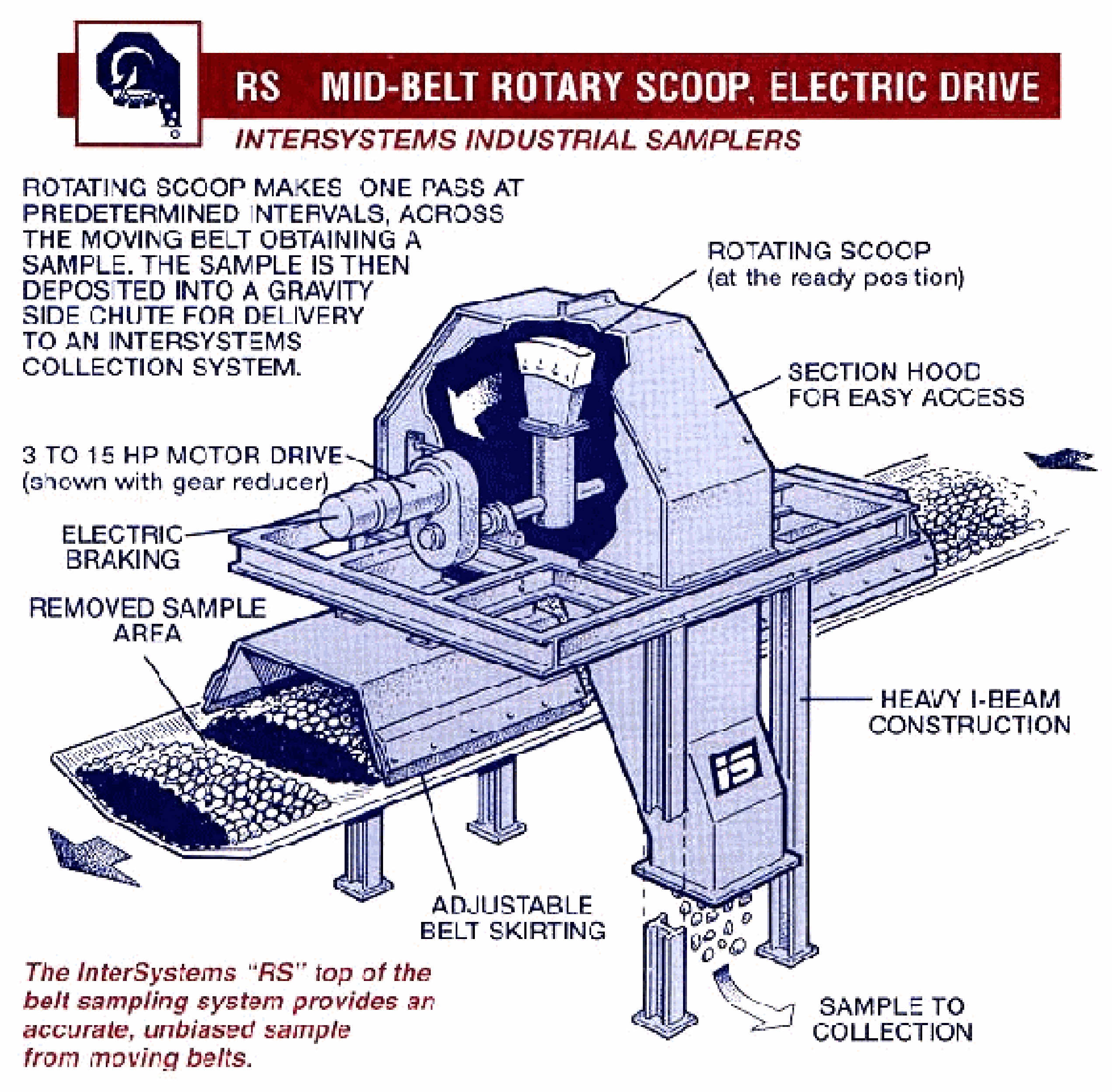
1.Raw coal conveyor
2.Cross belt bucket sampler
3.Feeding belt
4. Crusher
5.Rotary tube divider
6.Bias valve
7.Buffer container
8.Feeding belt
9.Rotary tube divider
10.Sample bottles
11.Reject material conveyor

How samplers work.

A belt sampler, consists of a passage-chute section with an integral belt cutter, which travels at a predetermined speed. The cutter is supported on needle-bearing rollers from bar track, in order to cut through, and beyond, the coal stream with each pass. Timers can be provided to initiate the sampling process automatically at regularly scheduled intervals--typically, every 1 to 30 min.

The totally enclosed rotary sampler is adjustable for the number of cuts per hour. Normally, one cutter is furnished, which takes a sample of the entire width of the coal stream with each revolution of the drum. Additional cutters can be spaced about the drum to increase the amount taken.

Power Coal Handling Feb.1974 page S-10

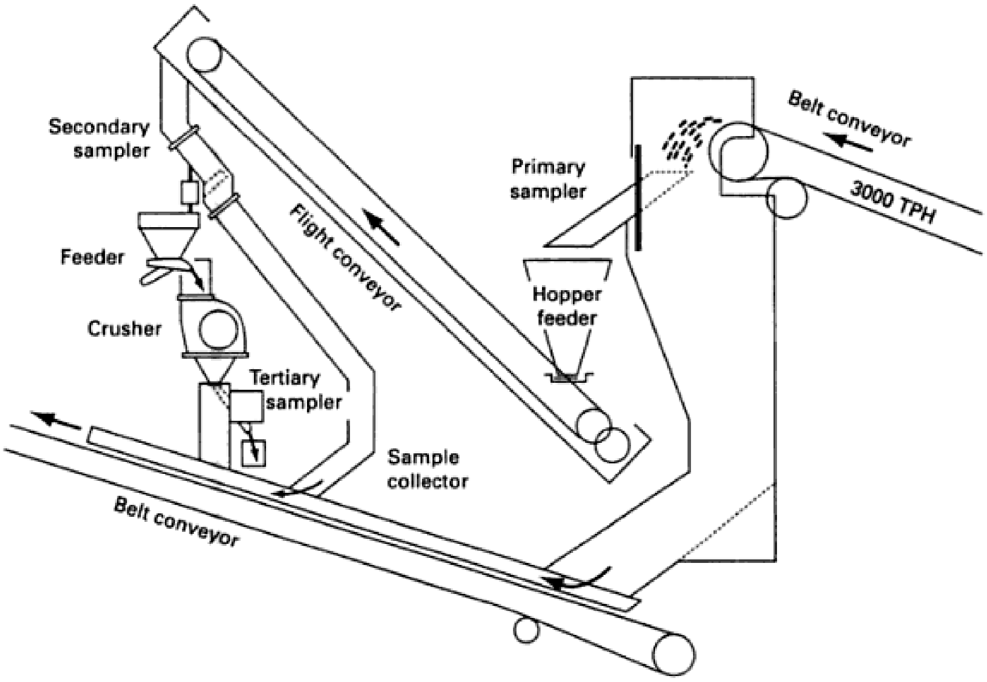


RS MID-BELT ROTARY SCOOP, ELECTRIC DRIVE

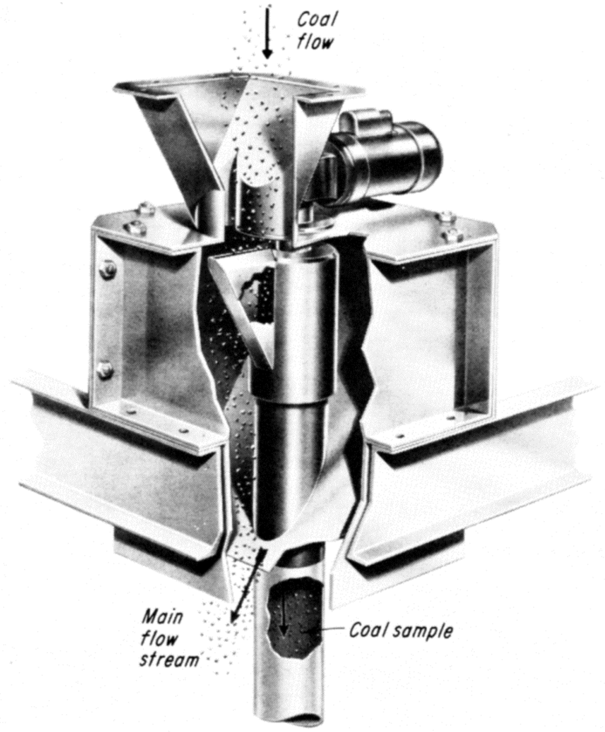
INTERSYSTEMS INDUSTRIAL SAMPLERS

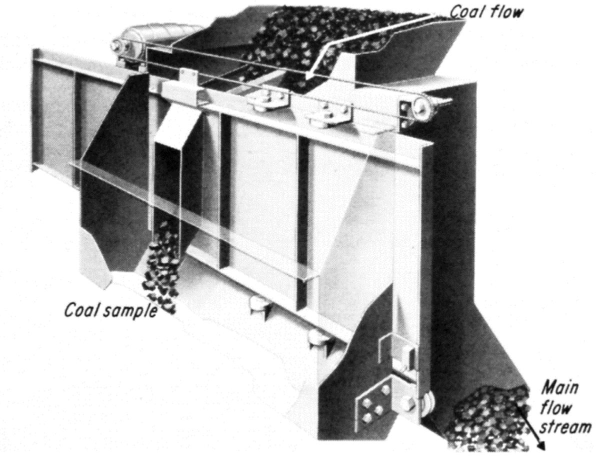
ROTATING SCOOP MAKES ONE PASS AT PREDETERMINED INTERVALS, ACROSS THE MOVING BELT OBTAINING A SAMPLE. THE SAMPLE IS THEN DEPOSITED INTO A GRAVITY SIDE CHUTE FOR DELIVERY TO AN INTERSYSTEMS COLLECTION SYSTEM.

The InterSystems "RS" top of the belt sampling system provides an accurate, unbiased sample from moving belts.



Mechanical sampling system. (*Source: Coal Preparation, 5th ed., Society for Mining,*





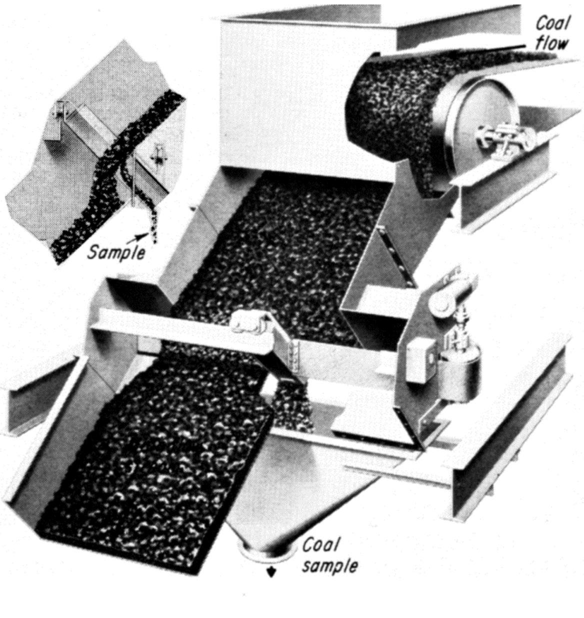


Plate samplers typically are extra-heavy-duty units that are designed primarily for high tonnages (upper right). Belt samplers are smaller, generally handling up to about 3000 tph in the large sizes (lower right). Rotary-drum samplers operate continuously, and usually are used to reduce the gross sample (above)

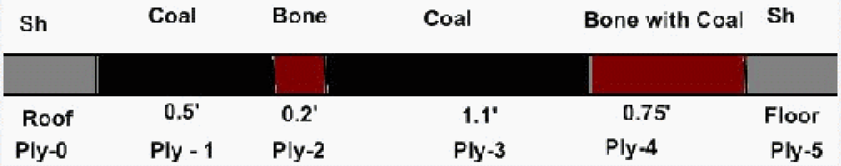
How is a coal sample taken at the mine?

A mine sample is taken at the selected point in the mine by cutting away the coal face for a width of 1 foot and for the entire height of the bed to a depth of at least one inch. The sample is then cut as a "channel" 2 inches deep and 6 inches wide in harder coals, or 3 inches deep and 4 inches wide in the softer coals, from roof to floor, down the middle of the foot wide cut previously made in the coal face. The sample is collected on a sampling cloth spread on the mine floor, the impurities are rejected, and then it is sealed in a sampling can before leaving the mine.

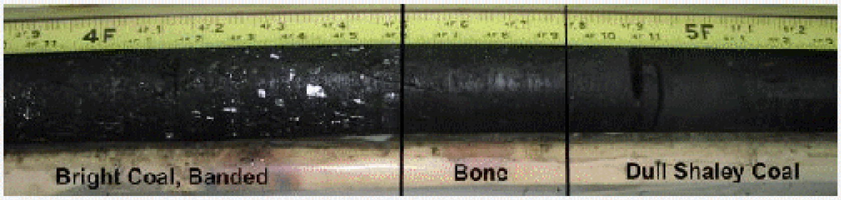
Kent's 12th page 2-21

Sampling coal in a surface mine in Indiana.

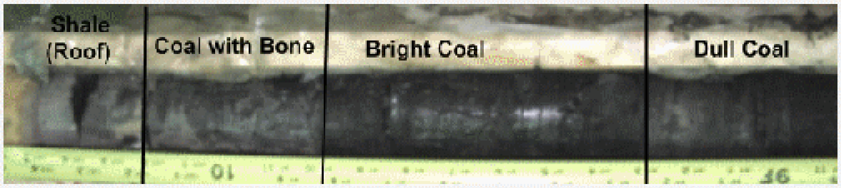
Getting a coal sample at the face of the seam



Ply Sampling Method



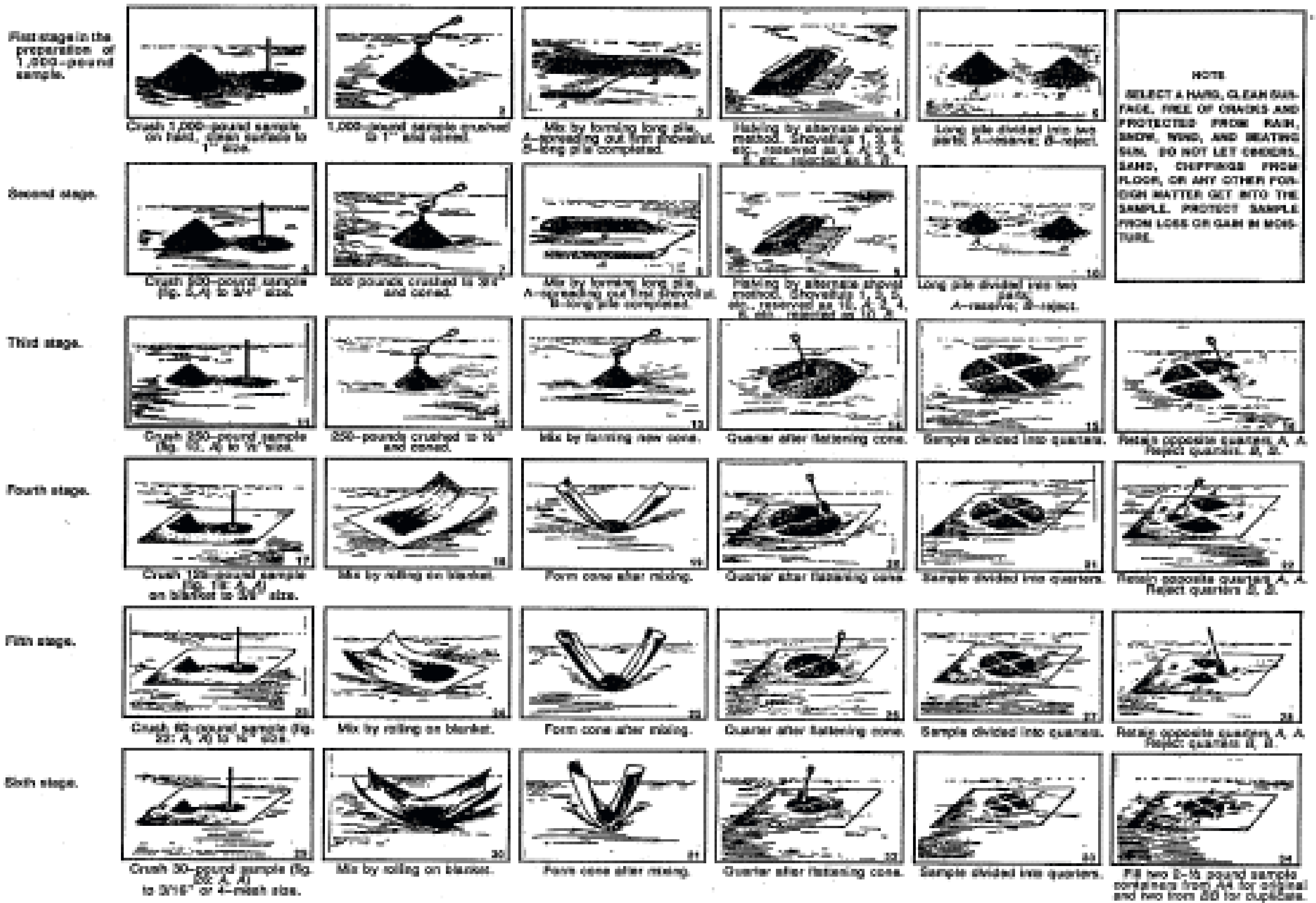
Coal Sampling Technique



Coal Sampling Technique

Coal sampling by drill coring. This is the modern method of coal sampling.

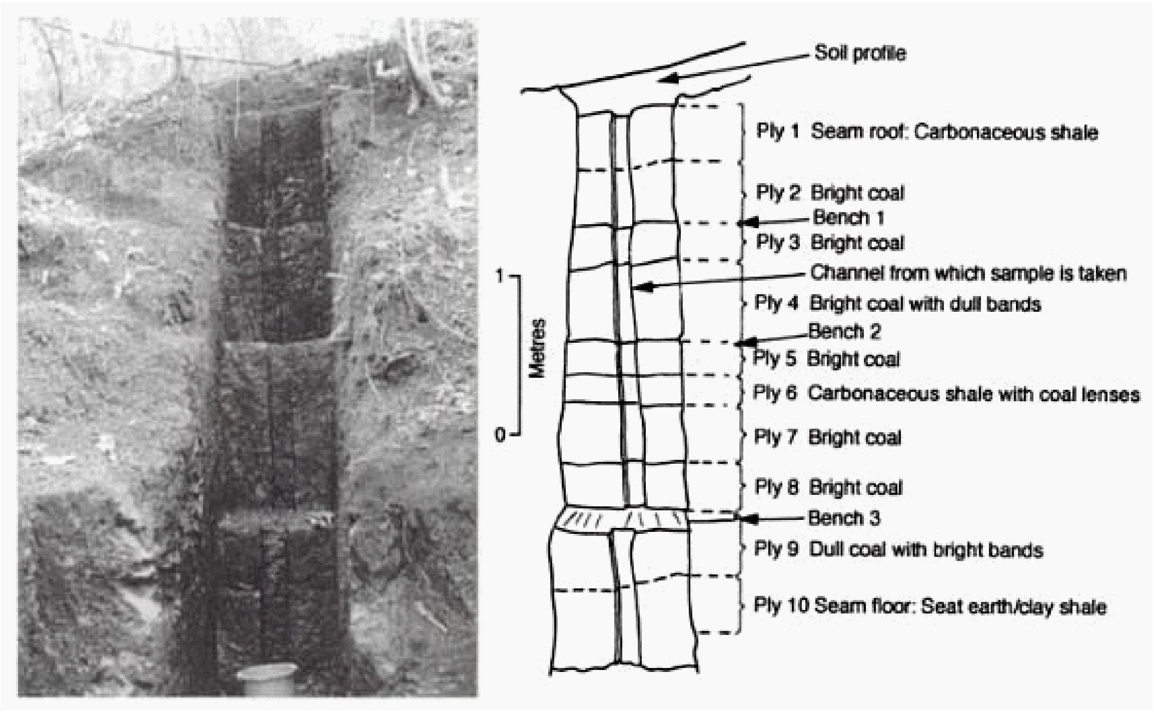
METHOD OF PREPARING A SAMPLE OF COAL BY HAND


First stage in the preparation of 1,000-pound sample.
Crush 1,000-pound sample on hard, clean surface to 1" size.
1,000-pound sample crushed to 1" and coned.
Mix by forming long pile. A–spreading out first shovelful. B–long pile completed.
Halving by alternate shovel method. Shovelfuls 1, 3, 5, etc., reserved as A; 2, 4, 6, etc., rejected as B.
Long pile divided into two parts. A–reserve; B–reject.
NOTE
SELECT A HARD, CLEAN SURFACE, FREE OF CRACKS AND PROTECTED FROM RAIN, SNOW, WIND, AND BEATING SUN. DO NOT LET CINDERS, SAND, CHIPPINGS FROM FLOOR, OR ANY OTHER FOREIGN MATTER GET INTO THE SAMPLE. PROTECT SAMPLE FROM LOSS OR GAIN IN MOISTURE.
Second stage.
Crush 500-pound sample (fig. 5, A) to 3/4" size.
500 pounds crushed to 3/4" and coned.
Mix by forming long pile. A–spreading out first shovelful. B–long pile completed.
Halving by alternate shovel method. Shovelfuls 1, 3, 5, etc., reserved as 10, A; 2, 4, 6, etc., rejected as 10, B.
Long pile divided into two parts. A–reserve; B–reject.
Third stage.
Crush 250-pound sample (fig. 10, A) to 1/2" size.
250-pounds crushed to 1/2" and coned.
Mix by forming new cone.
Quarter after flattening cone.
Sample divided into quarters.
Retain opposite quarters A, A. Reject quarters B, B.
Fourth stage.
Crush 125-pound sample (fig. 16, A, A) on blanket to 3/8" size.
Mix by rolling on blanket.
Form cone after mixing.
Quarter after flattening cone.
Sample divided into quarters.
Retain opposite quarters A, A. Reject quarters B, B.
Fifth stage.
Crush 60-pound sample (fig. 22, A, A) to 1/4" size.
Mix by rolling on blanket.
Form cone after mixing.
Quarter after flattening cone.
Sample divided into quarters.
Retain opposite quarters A, A. Reject quarters B, B.
Sixth stage.
Crush 30-pound sample (fig. 28, A, A) to 3/16" or 4-mesh size.
Mix by rolling on blanket.
Form cone after mixing.
Quarter after flattening cone.
Sample divided into quarters.
Fill two 2–15 pound sample containers from AA for original and two from BB for duplicate.

METHOD OF PREPARING A SAMPLE OF COAL BY HAND. THE NECESSARY TOOLS ARE A SHOVEL, TAMPER, BLANKET MEASURING ABOUT 8 BY 8 FEET, BROOM, AND RAKE. THIS COAL IS RAKED WHILE BEING CRUSHED, SO THAT ALL LUMPS WILL BE CRUSHED. FLOOR OR BLANKET IS SWEPT CLEAN OF DISCARDED COAL EACH TIME AFTER SAMPLE IS HALVED OR QUARTERED.

This process shows how a 1000 pound coal sample is crushed and then continually split into smaller sizes until it is down to 15 pounds.

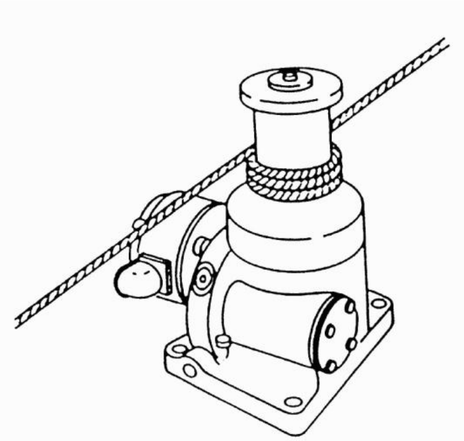
Sampling the face of the coal seam


Soil profile
Ply 1 Seam roof: Carbonaceous shale
Ply 2 Bright coal
Bench 1
Ply 3 Bright coal
Channel from which sample is taken
1
Metres
0
Ply 4 Bright coal with dull bands
Bench 2
Ply 5 Bright coal
Ply 6 Carbonaceous shale with coal lenses
Ply 7 Bright coal
Ply 8 Bright coal
Bench 3
Ply 9 Dull coal with bright bands
Ply 10 Seam floor: Seat earth/clay shale

Name five different types of coal unloading equipment.

1. Car and barge movers
2. Car-thawing equipment
3. Car shakers, unloaders
4. Rotary-car dumpers
5. Cranes and buckets

Power February 1974 page S-12

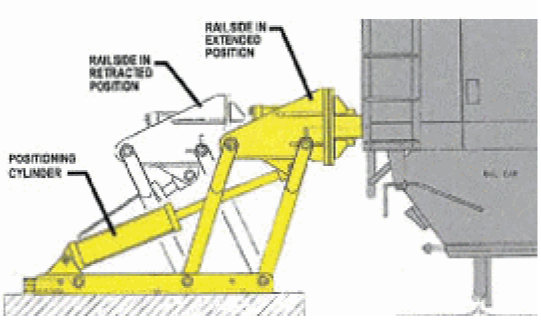


Capstan Winch for pulling rail cars and barges into position over the grizzly bars of a rail car dumping station. The rope grips itself with tremendous pulling power.

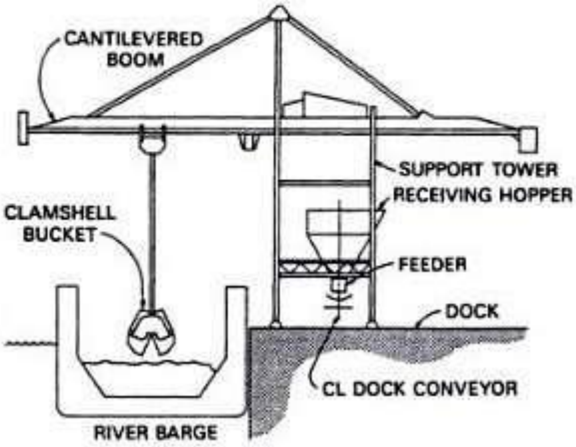
Capstan Winch

Rail Car thawing shed using infra-red heaters

Navco Side Railcar shaker in action



Navco Side Railcar shaker



Barge unloader

Navco Overhead Rail Car Shaker

Describe the difference between a coal breaker and a coal crusher.

Breakers break the coal by gravity, with a minimum production of fines. It has a large cylinder (typically 9 to 12 ft. in diameter and 20 to 30 ft. long), which rotates at slow speed, normally 20 rpm. The cylinder, constructed of perforated steel plates, is fitted with radial lifting shelves that carry coal until the angle of the shelf permits coal to drop. Crushers reduce the size of the coal to a specific size by means of putting the coal between rollers and a steel plate or two rollers.

Power Feb. 1974 page S-21.

Name and describe coal crushers and breakers

Single-roll crushers normally used for reducing run-of-mine coal to a maximum size of 1 1/4 to 8 in. have a toothed roll, which crushes coal against a breaker plate.

Double-roll crushers have two rolls usually both toothed or grooved, which revolve and crush coal between them.

Hammermills use the centrifugal force of swinging hammers or rings striking the coal to produce the crushing action.

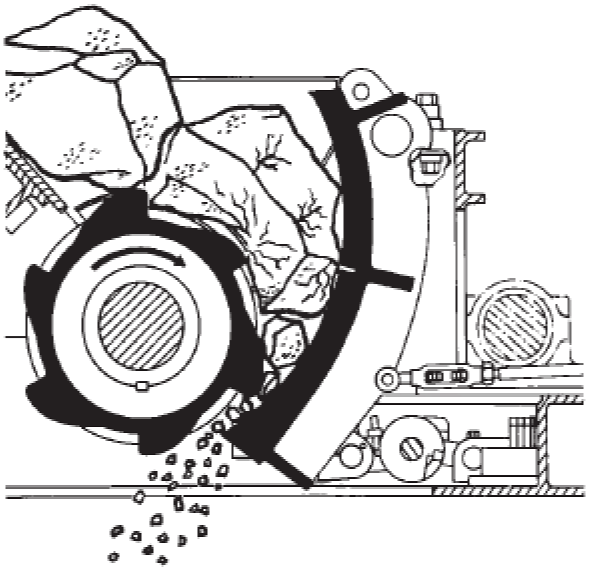
Bradford Breakers are revolving drums with shelves that pick up the coal and screens that size the coal

Power Feb. 1974. w. S-21

SINGLE ROLL CRUSHER

This type of crusher employs methods of crushing that differ greatly from impact style crushers. Instead of a rotor with free swinging hammers, the single roll crusher has a roll assembly consisting of a roll shaft and a fabricated roll shell with integral fixed teeth.

In the single roll crusher, three different methods of reduction occur: Impact, Shear and Compression.



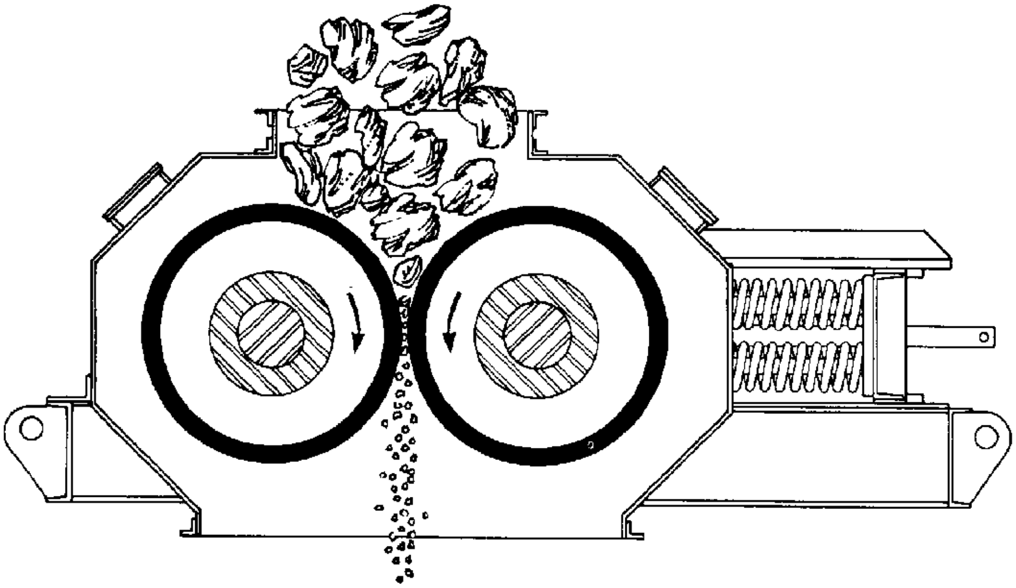
Single Roll Crushers reduce large input by a combination of shear, impact and compression. They are noted for low headroom requirements and large capacity.

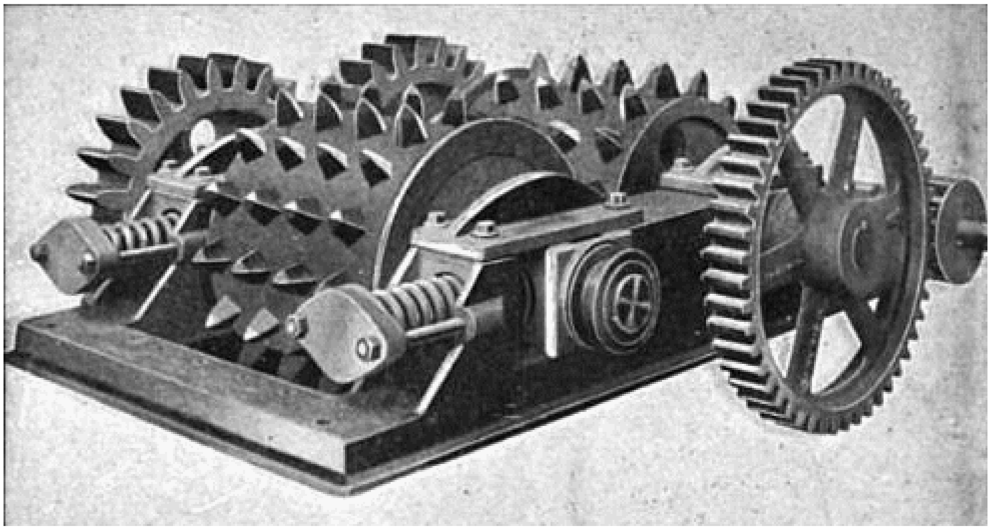
DOUBLE ROLL CRUSHER

These Double Roll Crushers are employed on numerous materials, including petroleum coke, lime, carbon anodes, shale, aluminum dross, coal and clinker.

With Pennsylvania Double Rolls, the user obtains good control over product size, an important consideration in many applications. All crushing is produced by compression and, since no shearing or attrition occurs, fines are kept to an absolute minimum and wear life of the rolls is maximized.

Pennsylvania supplies three roll surfaces: smooth, corrugated or slugger teeth.





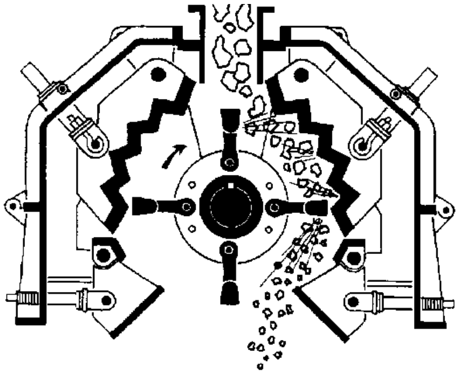
Double roll toothed crusher

HAMMERMILLS

Hammermills are among the oldest yet still the most widely used crusher designs. Although recent years have witnessed the introduction of new types of crushers, many are a refinement of the basic hammermill design to serve more specialized purposes.

Pennsylvania Hammermills crush material in two stages: First, the material is reduced by dynamic impact; crushing then occurs by attrition and shear in the second zone, where slight clearances exist between hammers and screen bars. This second zone is the final sizing zone for the product. Cages can be adjusted to regulate product top size and a tramp iron pocket is available on most models.

Hammermill



Hammermill

REVERSIBLE HAMMERMILL

Pennsylvania Reversible Hammermills are symmetrically designed crushers with a rotor that can be run clockwise or counter-clockwise. Reversal of the rotor permits the operator to utilize the opposite face of the hammer daily for maximum hammer sharpness. This ability to reverse totally eliminates the requirements of manual hammer reversal. Reversal is done with a simple motor switch.

REVERSIBLE HAMMERMILL FOR COAL

Pennsylvania builds a Reversible Hammermill specifically for the reduction of coking coals, pulverizer and stoker coals, cyclone fuel and other finely crushed coal. To produce the fine product sizes required, a Pennsylvania Reversible Hammermill for coal has more rows of hammers than are found in the Reversible Hammermills used for stone or rock.

BRADFORD BREAKERS

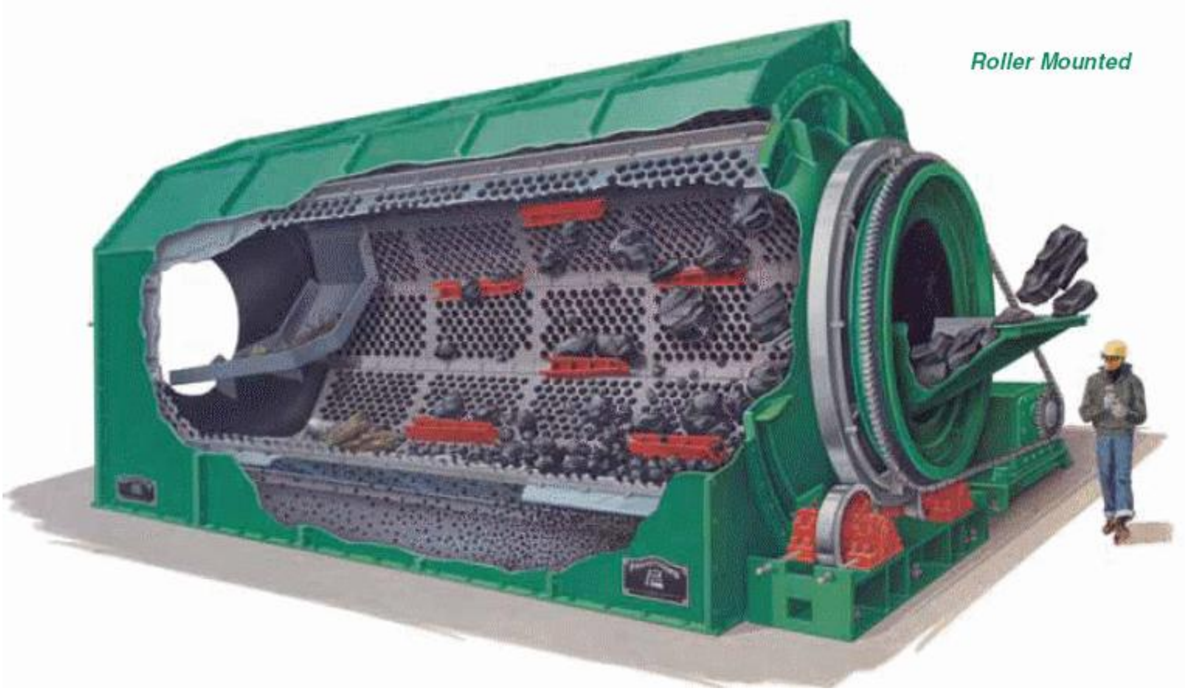
These machines are used for crushing, sizing of run-of-mine coal. They are used to produce a product that is relatively coarse, with minimum fines. They have been used since 1905.

Bradford Breakers crush by gravity impact only. A large cylinder made of perforated screen plates is fitted with internal shelves. As the cylinder rotates, the shelves lift the feed and, in turn, the feed slides off the shelves and drops onto the screen plates below, where it shatters along natural cleavage lines.

The size of the screen plate perforations determines the product size. Sized product falls through these perforations but over-sized pieces will again be lifted and dropped by the shelves until they too pass through the screen plates.

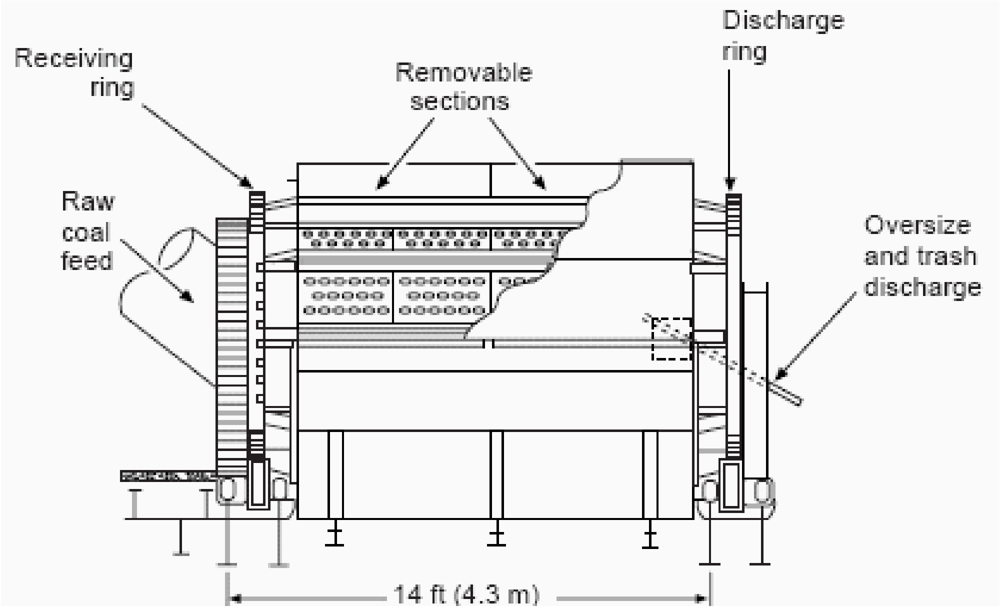
Tramp iron, lumber, or other uncrushable debris that enters the breaker along with the feed will flow to the discharge end of the cylinder. There, these uncrushables are scooped out continuously by a refuse plow which channels this debris out of the cylinder and into a disposal bin.

Breaker cylinders rotate at slow speeds of from 12 to 18 RPM depending upon cylinder diameter. Compared with most other crushers, Bradford Breakers are extremely long lived. Screen plates, for example, frequently last 10 years or more, crushing millions of tons of coal, and there are numerous examples of Pennsylvania Bradford Breakers in continuous service for upwards of forty years.

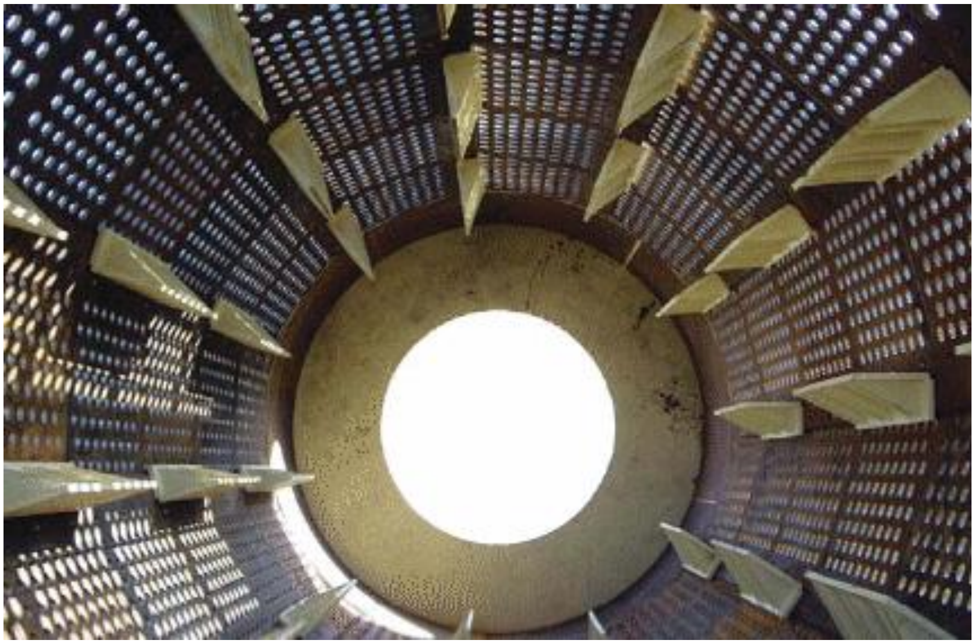


ROLLER MOUNTED OR TRUNNION MOUNTED BRADFORD BREAKERS

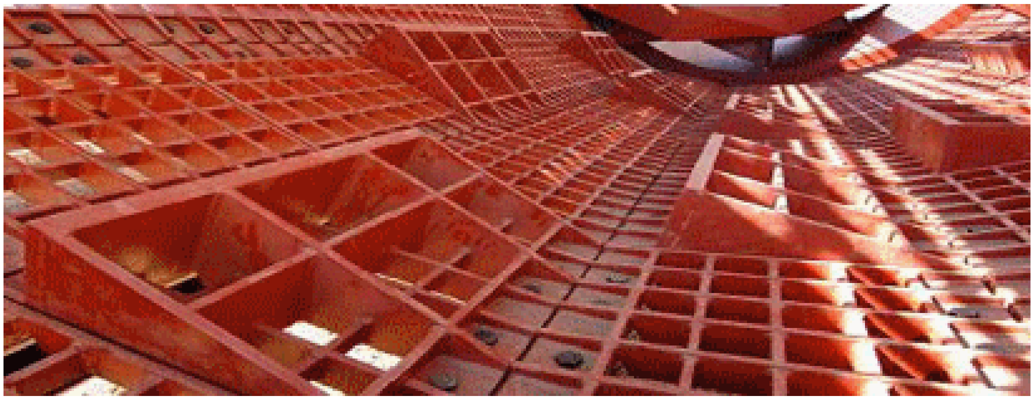
The roller mounted Bradford Breaker is suited for coal mines where the feed often includes unusually large pieces of coal. This model will readily accept these larger pieces of coal without blocking of the entry. In coke plants and central power stations where feed sizes do not include such large pieces, the trunnion mounted Bradford Breaker is sometimes preferred. With either design, the breaking action is exactly the same, the only difference being in the method of mounting and driving the rotating cylinder.



Bradford Breaker



Inside a Bradford Breaker



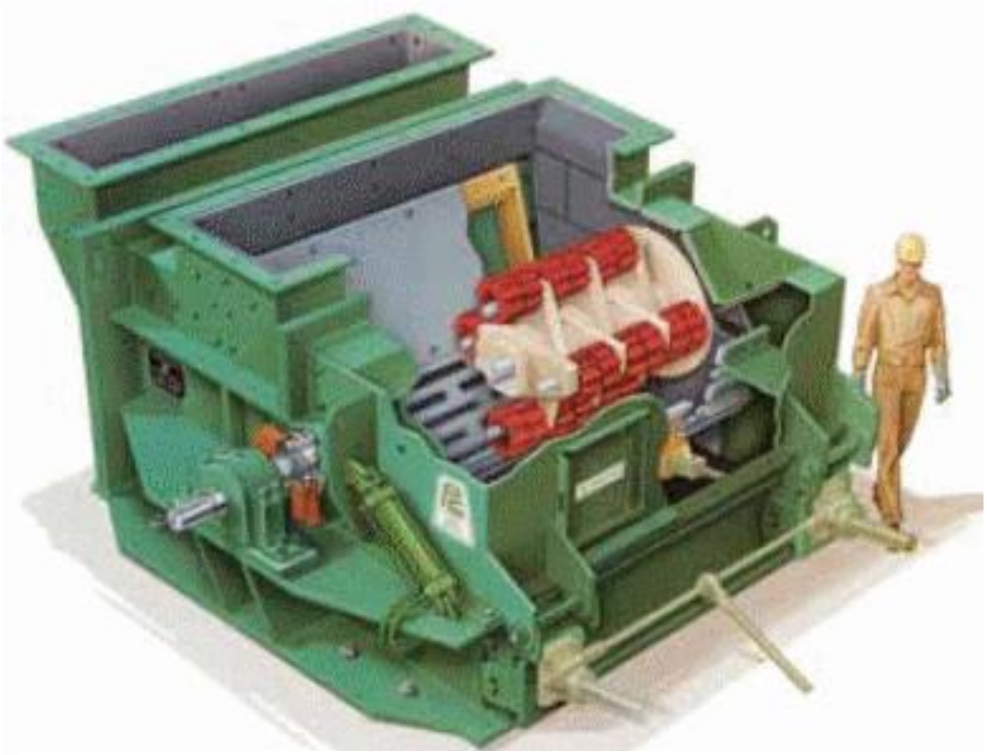
Inside another style of Bradford Breaker. Notice the easily replaceable sections.

GRANULATORS

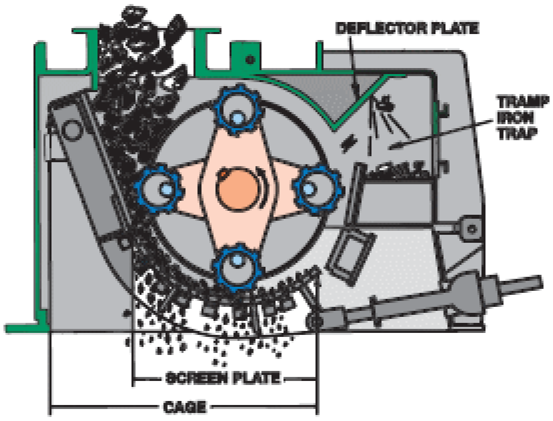
Pennsylvania Granulators are a type of crusher that uses rows of ring hammers which crush with a slow, positive rolling action. This type of crushing produces a granular product with minimum fines. Granulators are used for crushing coals, particularly for power plants.

Granulators crush by a combination of impact and rolling compression, producing high reduction ratios at high capacities. Product size is determined by screen openings, and is adjusted by changing the clearance between the cage and the path of ring hammers. Granulators also have a tramp iron pocket for continuous removal of pyrites and other hard rejects from the crushing zone.

This series of crushers includes the Koal King Granulator, a machine specifically designed for preparation of pulverizer feed for power generating plants. The Koal King will handle virtually any type of coal, including low quality coals that are wet, frozen, high in fines, or high in ash content, with virtually no plugging problems.



King Koal Granulator



COALPACTOR

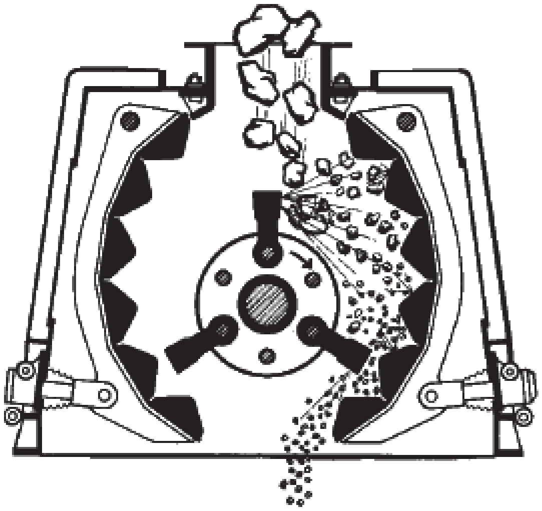
Coalpactors were originated by Pennsylvania Crusher Corporation to pulverize coking coals and to produce an optimum percentage of product below 1/8", but with a minimum amount of fines (100 mesh or smaller).

A Pennsylvania Coalpactor is similar to an impactor. It has breaker plates that are fully adjustable from outside of the frame to enable operators to vary the degree of pulverization. This same feature allows maintaining a uniform product size throughout the life of hammers and breaker plates.

Reversing Feature

The Coalpactor rotor may run either clockwise or counter-clockwise to provide for equal wear on both hammer faces. This helps to extend hammer life and to reduce maintenance problems. To facilitate servicing, all internal parts of the machine are readily accessible.

Pennsylvania Coalpactors have largely replaced other types of crushers for pulverizing coking coals because the Coalpactor will maintain rated capacity even when the coal is wet.



The bottom of the Pennsylvania Reversible Impactor is open and the sized material passes through almost instantaneously. Liberal clearance between hammers and the breaker blocks eliminates attrition, and crushing is by impact only.

Why is the use of coal crushers not as important today as they were before continuous mining machines were used in underground mines?

In the early days coal was mined with shovels, picks and dynamite. When the dynamite was exploded coal was broken off in big chunks, as well as, small pieces. Today continuous mining machines auger at the coal removing the coal in fairly uniform sizes. This is why crushers were used more years ago than now.

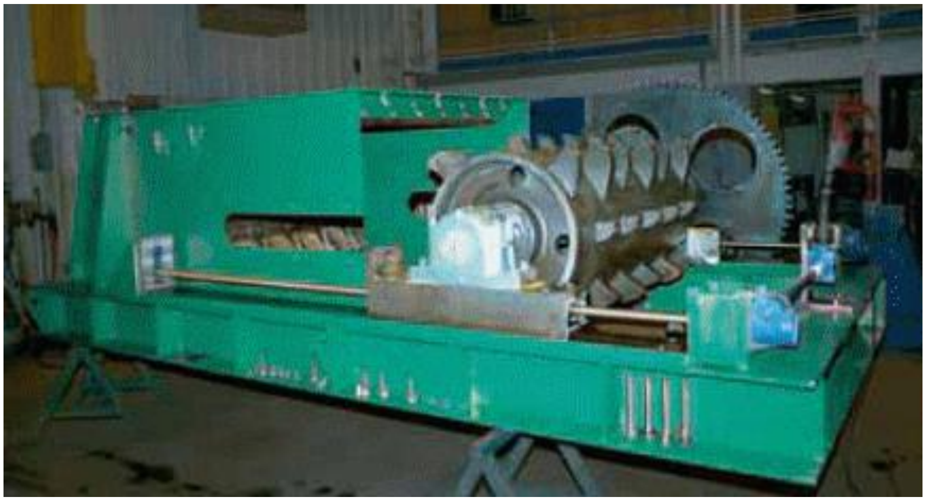
Babcock & Wilcox Steam 40th edition pages 11-1 to 11-2

FROZEN COAL CRACKER

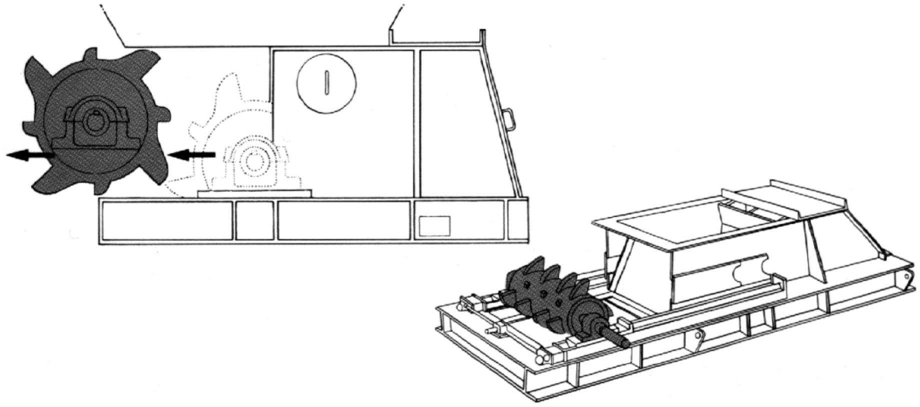
This type of machine is basically a single roll crusher. It differs from other Pennsylvania single roll crushers in the drive mechanism.

Though it utilizes the basic single roll design crushing actions, this particular machine has an extremely wide feed opening which permits the use of open-throated hoppers to choke feed large lumps of coal into the machine. It will reduce coal to a nominal 6" or 8" product size.

Freezing of the coal can occur anyplace, including railcars and stockpiles, causing stoppages in handling or conveying. These frozen coal lumps will often fall from conveyors or become wedged in hopper throats. For this reason, Pennsylvania Frozen Coal Crackers have a low profile, so as to fit into existing coal handling systems. The machine is often installed directly below the railcar delivery hoppers or at the outdoor stockpile.

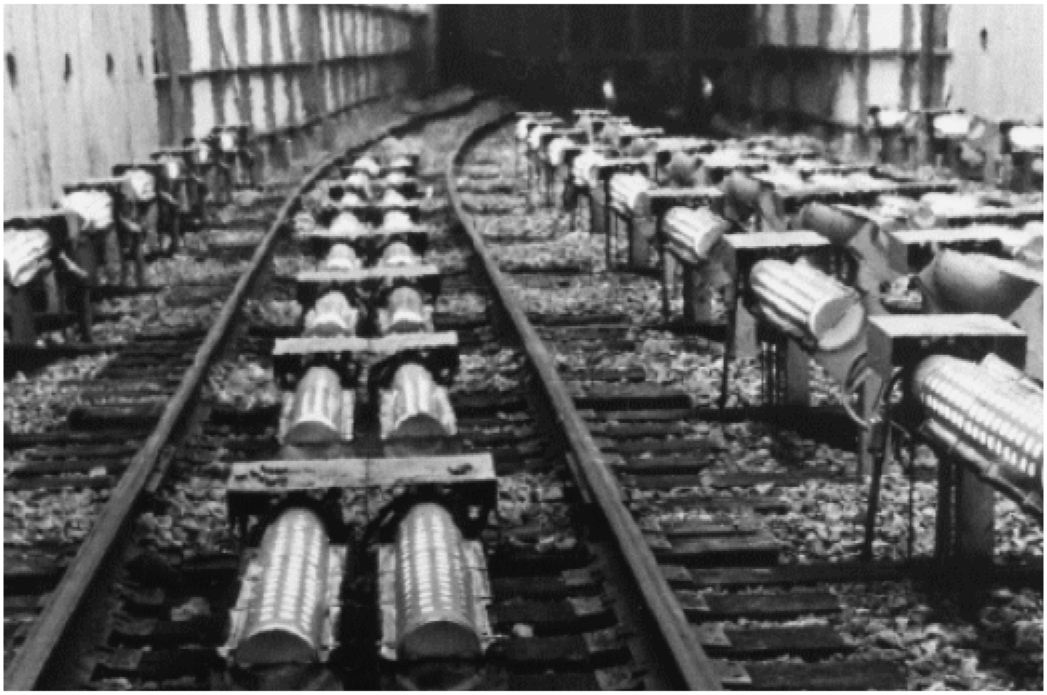


Frozen Coal Cracker

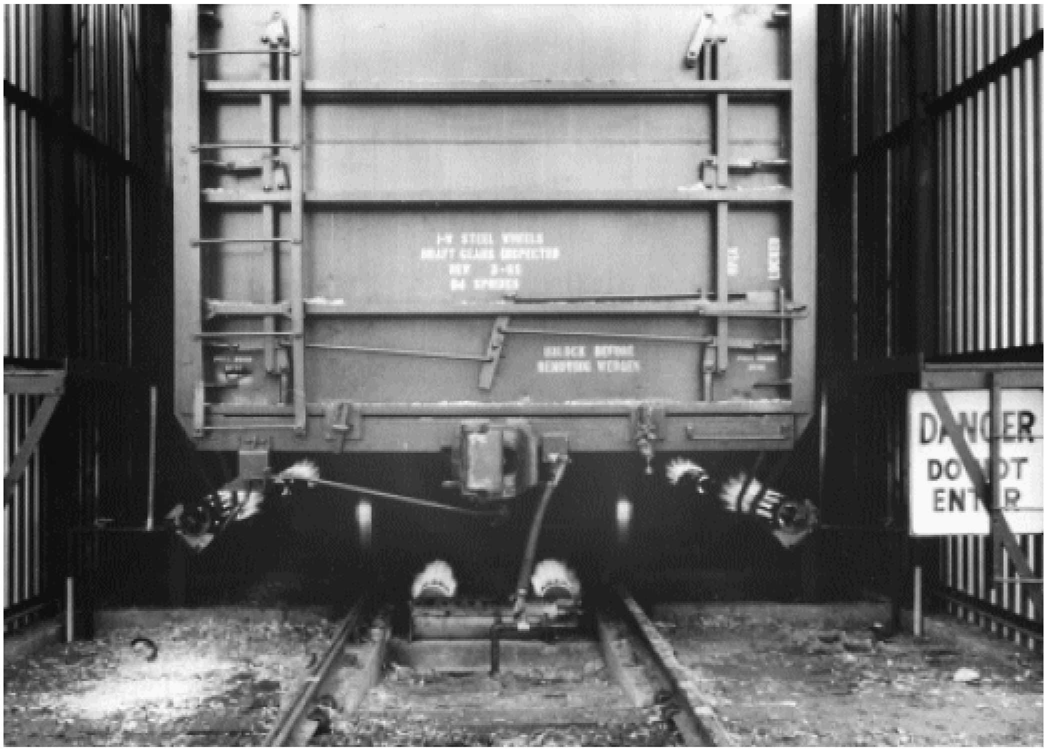


Frozen Coal Cracker roll can be moved out of the way in the summer so that the coal will flow more easily to the hopper.

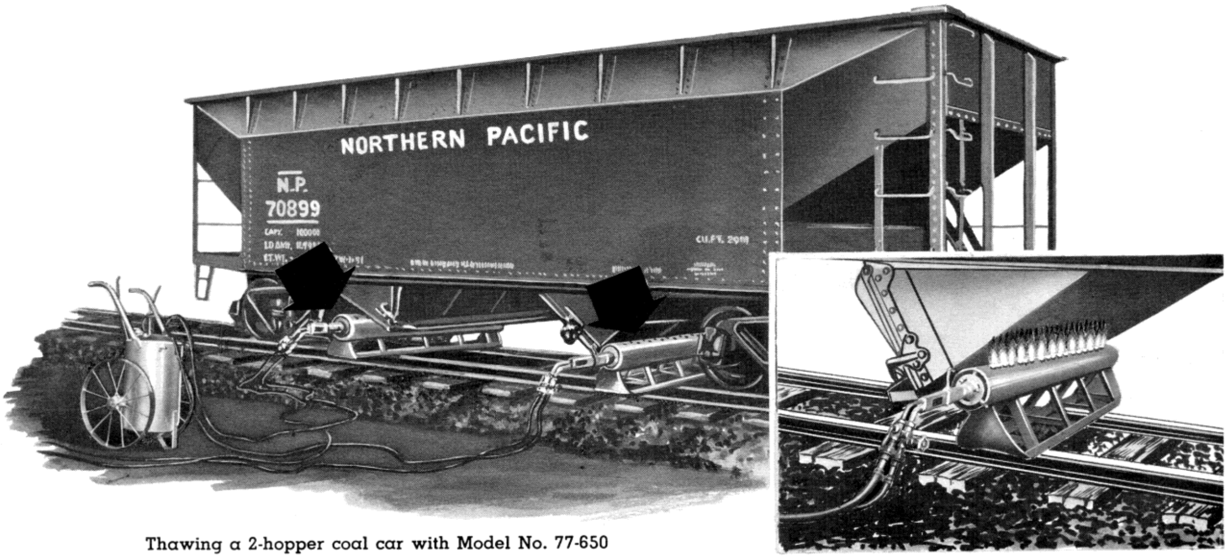
In order to thaw the frozen coal from the rail cars, infrared heaters in a thawing shed are used to thaw the coal. Oil fired or natural gas fired heaters called “hot dogs” are used in some locations



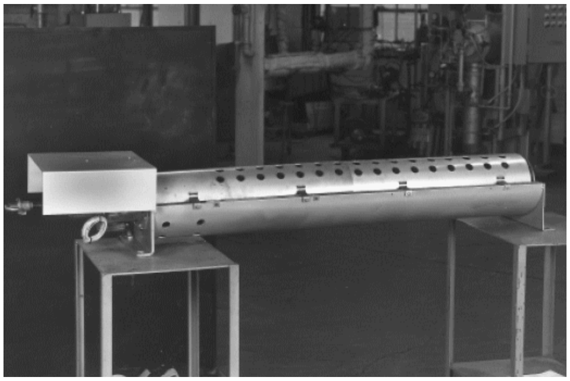
Infrared heaters located underneath and on the sides of the thawing shed



Infrared heaters underneath the rail car

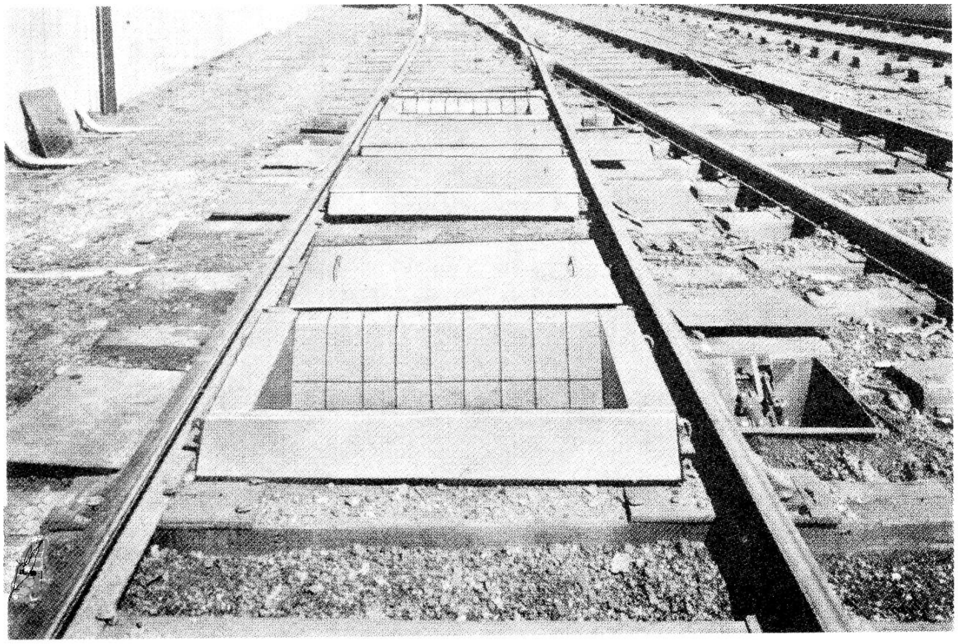


Thawing a 2-hopper coal car with Model No. 77-650
Thawing Tube Equipment.

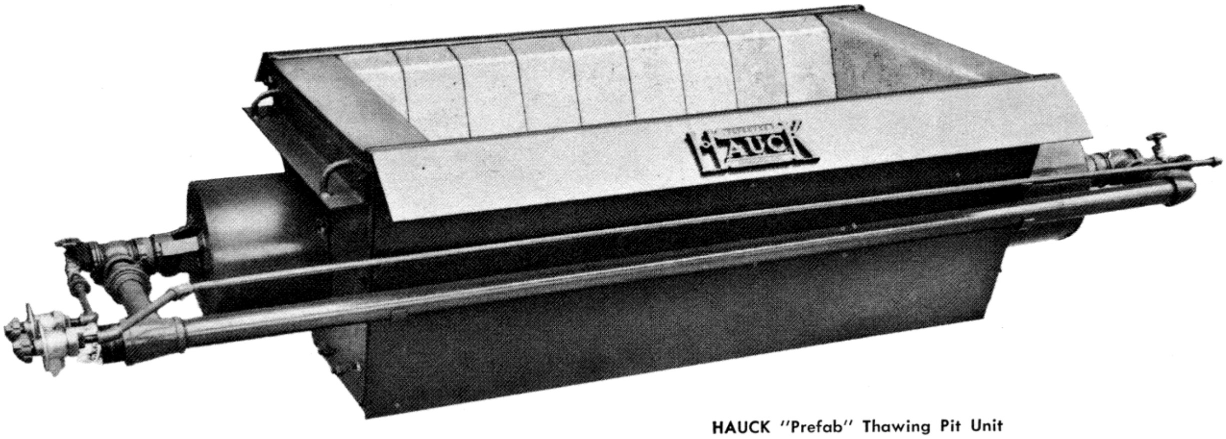


Hot Dog Burner by North American Manufacturing Co.

Portable frozen coal car thawer by Hauck

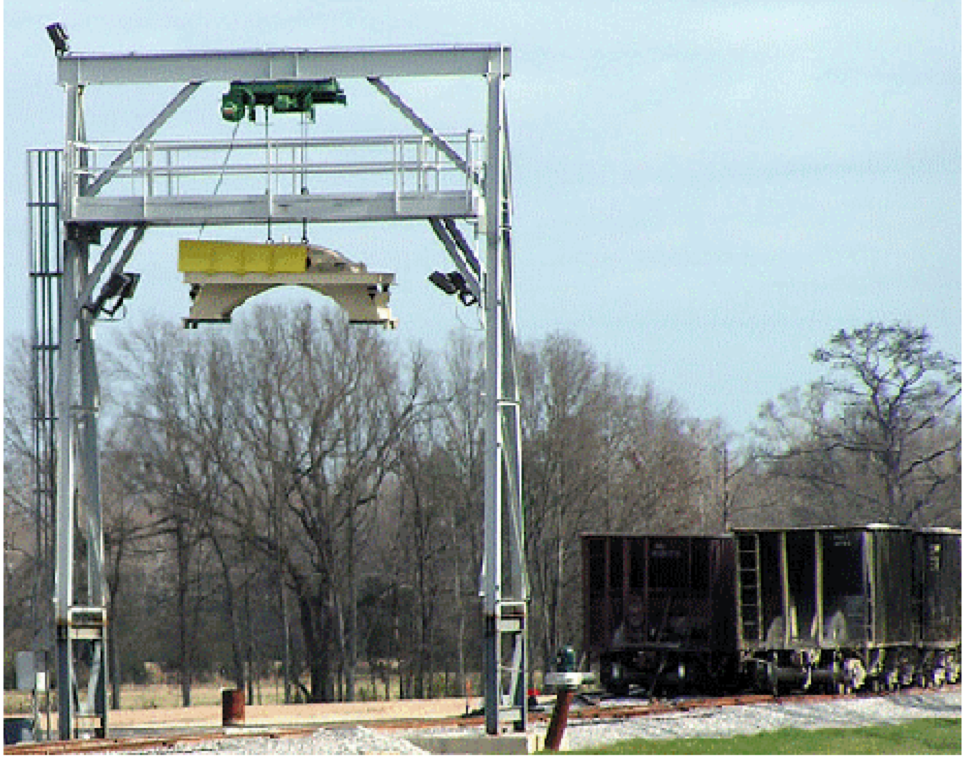


Thawing pits installed underneath the rails.



HAUCK "Prefab" Thawing Pit Unit

Bottom Dump plates under railcar sitting over a Hauck thawing pit



Overhead rail car shaker

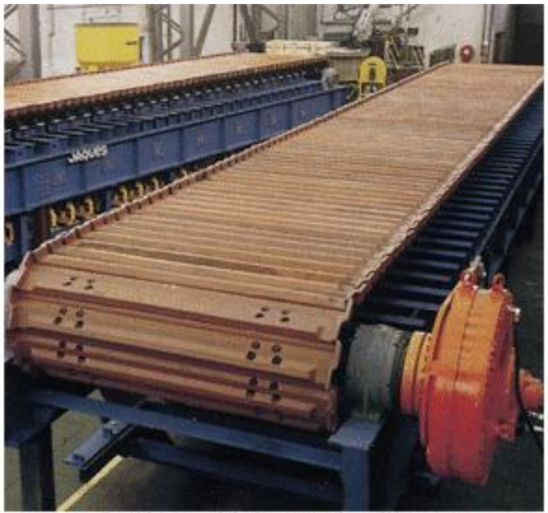
What is the difference between an unloader and a feeder?

Unloaders deliver coal at an unmetered rate. Feeders are devices that deliver coal at a controlled rate, from a storage area to a point where a conveyor can handle it conveniently for transport.

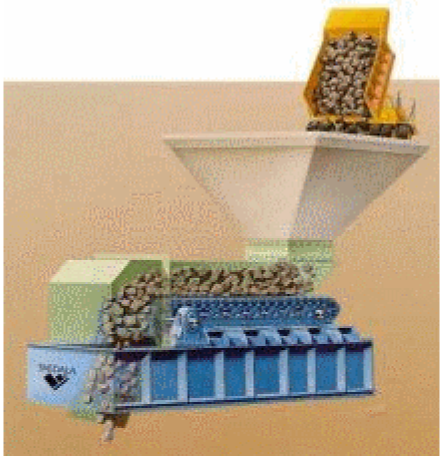
Power Feb. 1974. page S-14

Name six types of coal feeders.

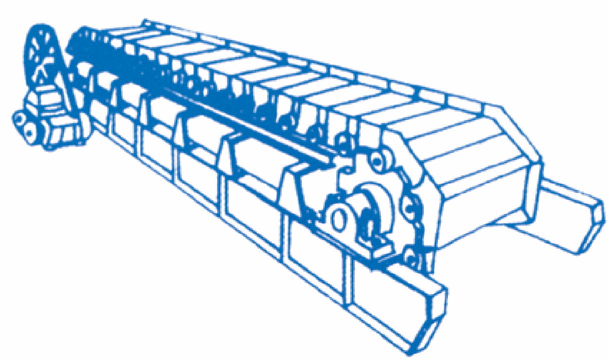
1. Apron feeders, heavy and rugged in construction, consisting of overlapping steel pans (18 in. wide and up) mounted on double rolls of steel rolling chain. They differ from the familiar flight conveyor in that the pans carry the coal rather than flights that scrape it along.



apron feeders with integral spillage conveyor



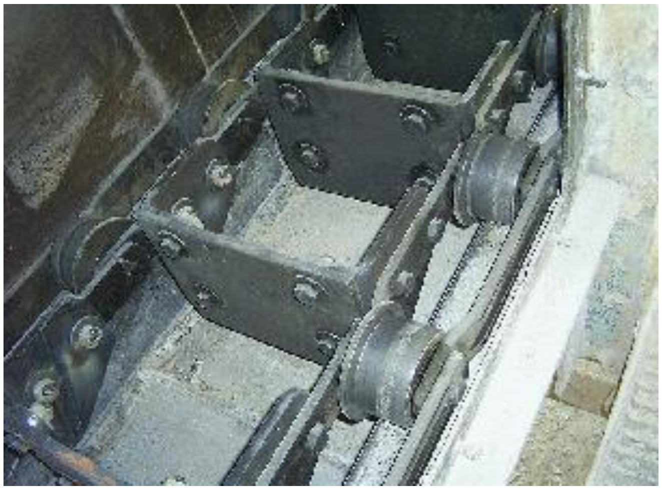
Apron Feeder



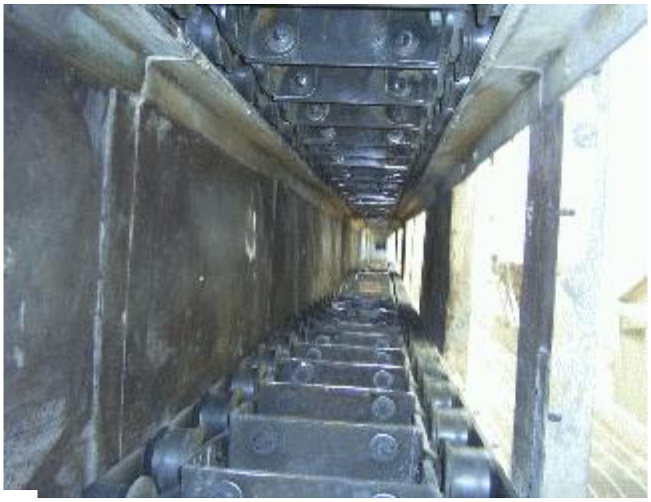
Apron Feeder

Portable Apron Feeder

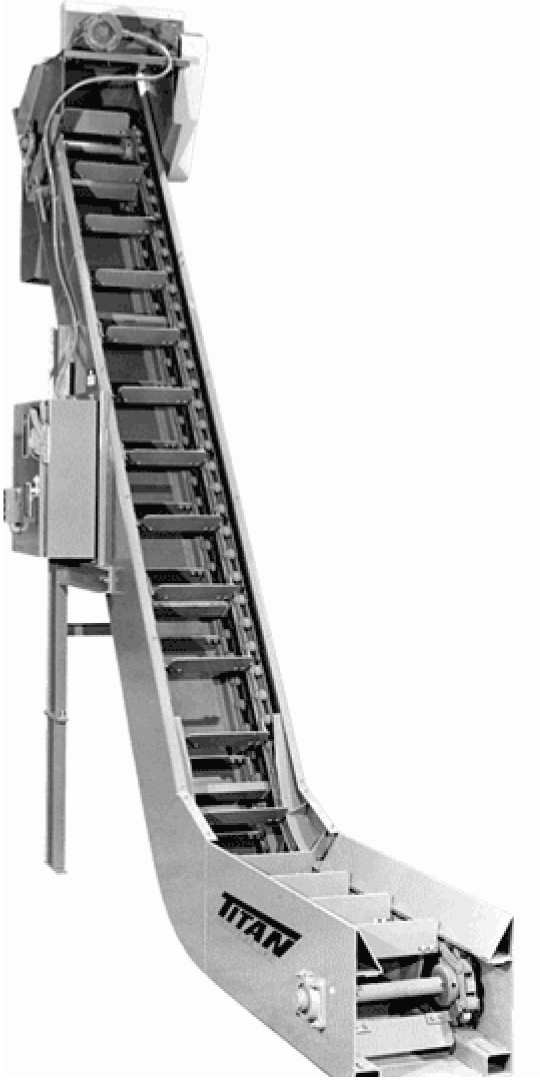
2. Bar-flight and drag-flight feeders consist of bars of flights attached to one or two strands of chain in a manner that permits the bars to slide along the flat bottom of a trough, dragging the coal.



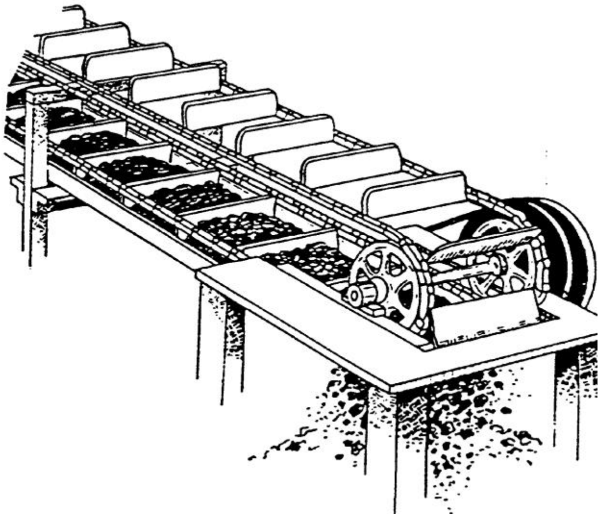
Flight Conveyor



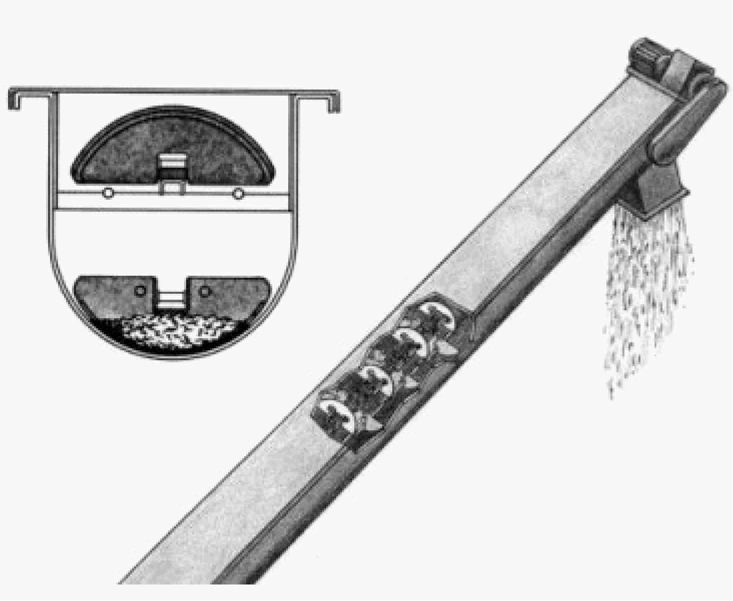
Flight Conveyor



Flight Conveyor for lifting coal to a higher elevation

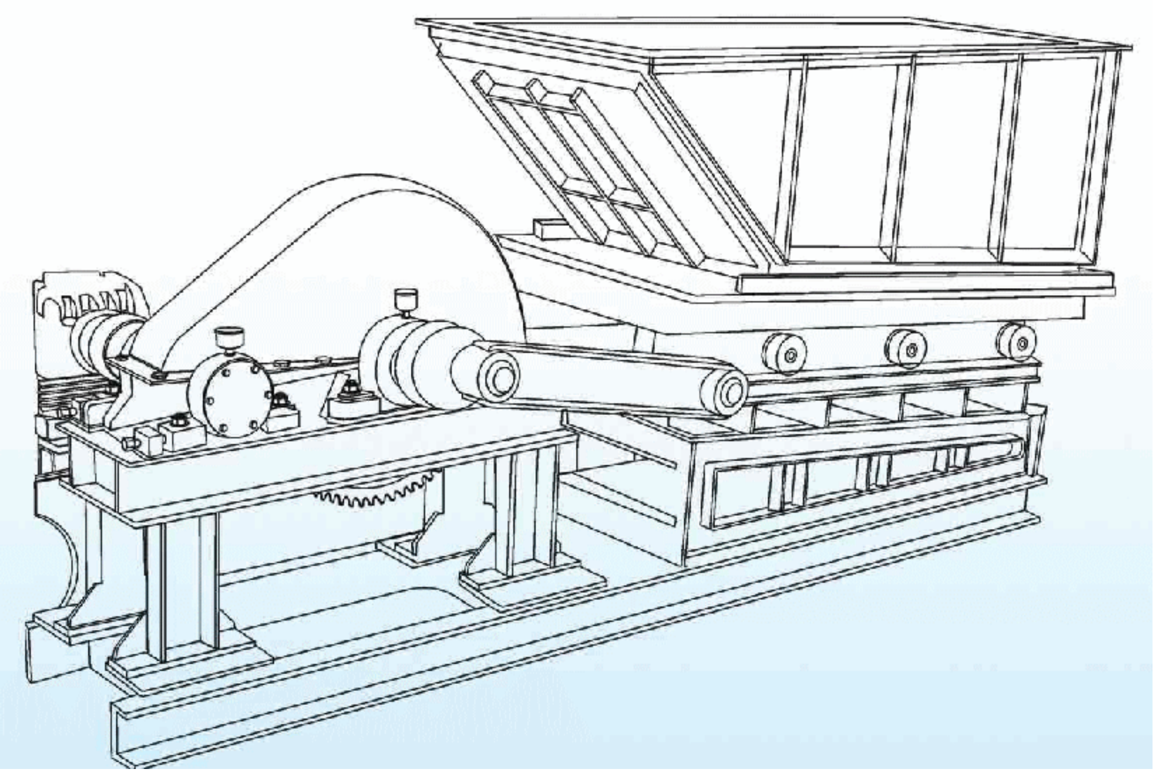


Drag Flight Conveyors

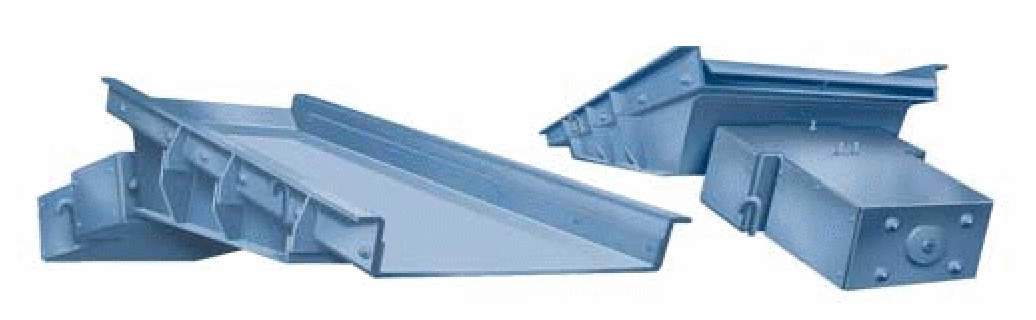


Single-Chain Drag - Flight conveyor for elevating coal

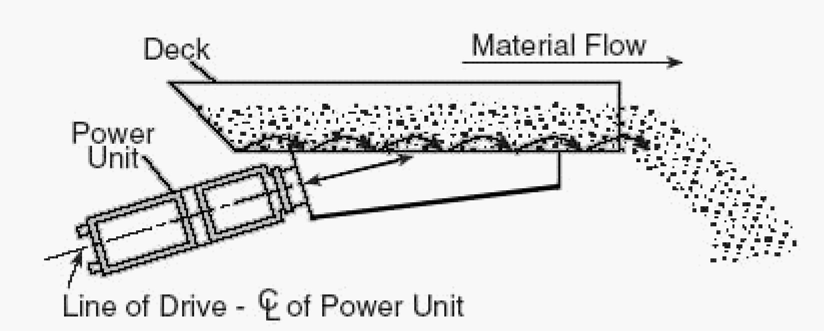
3. Reciprocating feeders consists of a steel plate 6 to 9 ft. long, and 15 to 30 in. wide mounted on tracked wheels between guiding skirt plates. Rods connected to adjustable cranks or eccentrics drive the pan, from a motor. As the eccentrics revolve, they push the pan forward with its load of coal. Additional coal then falls from the hopper to the back end of the pan. On the return stroke, coal does not move back with the pan, and some falls off the end.



4. Vibrating feeders of modern design, a rotary vibrator drive creates a sinusoidal excitation force, which is transmitted and magnified through a spring system that holds the feeder pan. The result is a constant, straight line vibration of the trough system.

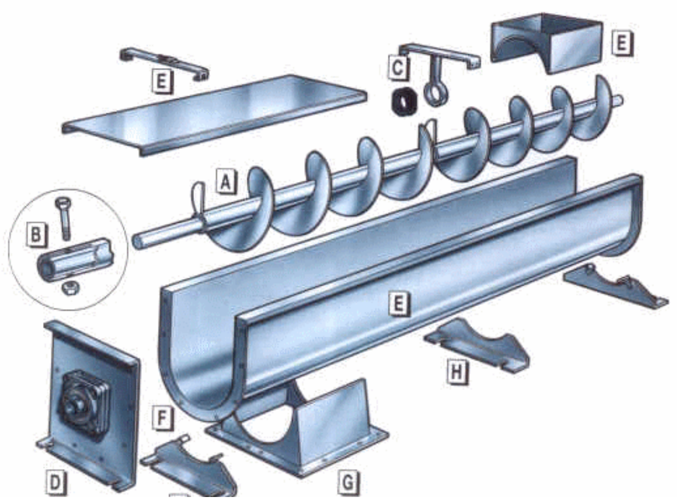


Jeffrey Rader HP Electromagnetic Vibrating Feeders

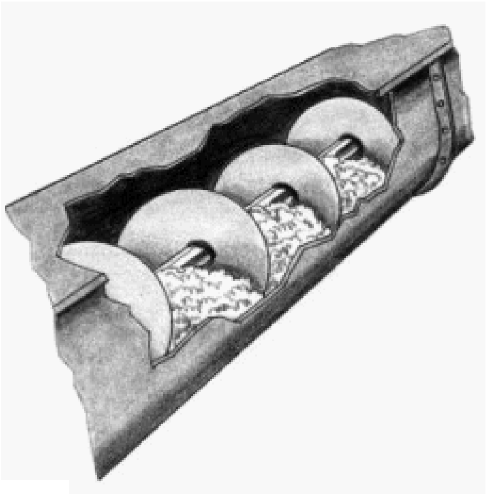


Electromagnetic Operation

5. Screw conveyors consist of a long-pitch steel-plate helix on a spindle, carried by bearings within a U ¬shaped trough. As the spindle rotates, coal moves forward under the thrust of the lower part of the helix and discharges through openings in the bottom or open end of the trough.



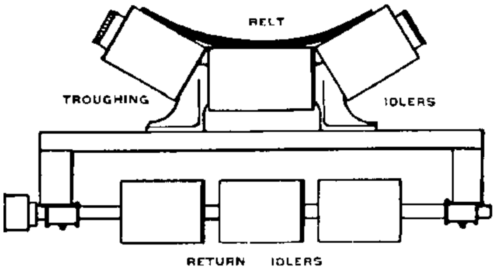
Screw conveyor components



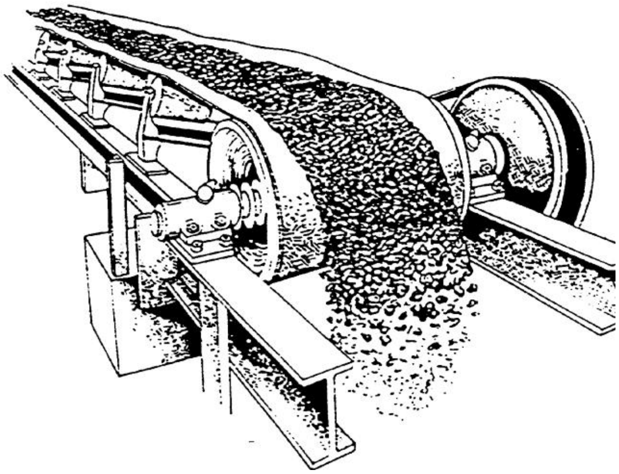
Screw Conveyor

6. Belt conveyors, smooth operation and uniform discharge make belt conveyors attractive as feeders. When so used, they are short, and have closely spaced idlers for support against the impact of hopper fed coal.

Power Feb. 1974, page S-14. S-15



Guide Pulleys, Robins Belt Conveyor.



Coal Conveyor

Coal Conveyor

Describe an ash system.

As slag tanks and dry ash hoppers slowly fill they must be emptied. There are three methods for removing ash from one place to another.

a. Mechanical conveyors are used on small installations.

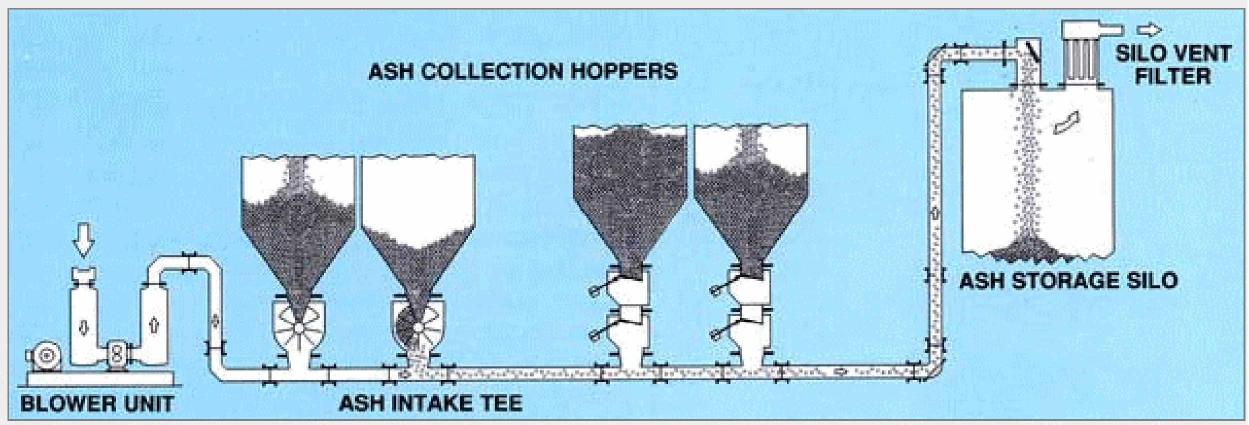
b. Hydraulic conveyors use water to move the ash.

c. Pneumatic systems use compressed air or a vacuum.

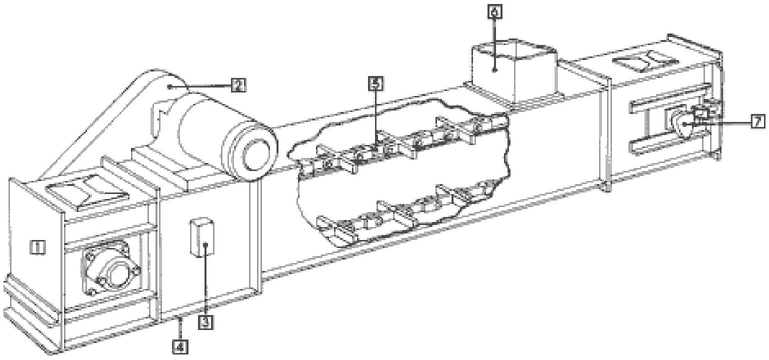
With hydraulic conveyors dry lumps of slag from furnace bottoms are transported in an open trench or a closed pipe by high pressure water jets or a centrifugal pump to a wet sump.

Pneumatic conveyors work best on dry flyash. The ash stream is often fed into the piping by feeders. This allows a limited amount of ash to enter the pipe to prevent overloading. Vibrators maintain a supply to the feeders. The ash and air are then fed into a separator which separates the air and ash by centrifugal force. The air from the separator passes through filters which catch any ash that has escaped the separator. All of the fly ash falls into a storage bin beneath. Water is mixed with the dust leaving the storage bin to prevent it from blowing away during transport.

Power Plant Steam and Mechanical Fundamentals Commonwealth Edison - Ash Removal page 15

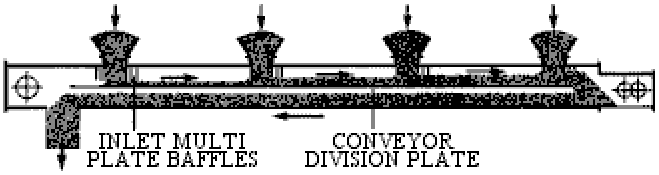


Pneumatic Blower unit blows the dry ash into the silo

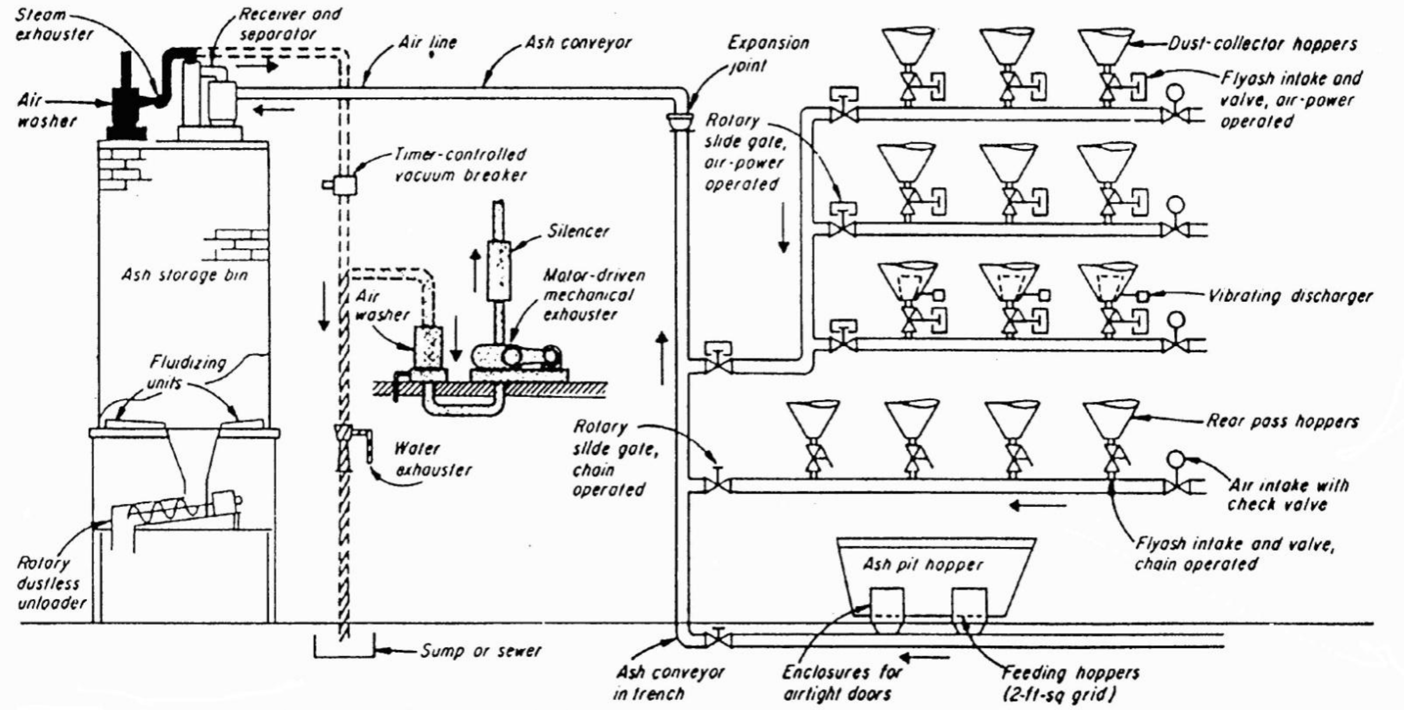


1 Totally enclosed casing
2 Integral or independently mounted drives
3 Safety choke detector
4 Single or multiple outlets
5 STOCK REDLER high strength conveyor chain
6 Single or multiple inlets
7 'RoCon' underspeed safety control switch

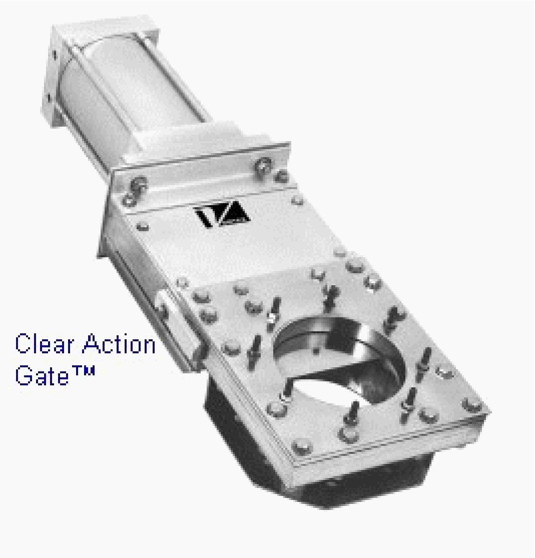
Wet ash unit conveys the ash with a drag chain



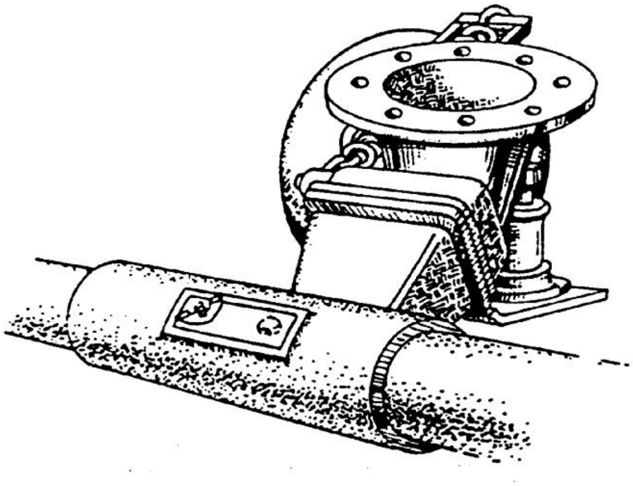
Drag chain with ash hoppers discharging above the drag chain


Steam exhauster
Receiver and separator
Air line
Ash conveyor
Expansion joint
Dust-collector hoppers
Flyash intake and valve, air-power operated
Air washer
Rotary slide gate, air-power operated
Timer-controlled vacuum breaker
Silencer
Ash storage bin
Motor-driven mechanical exhauster
Air washer
Vibrating discharger
Fluidizing units
Water exhauster
Rotary slide gate, chain operated
Rear pass hoppers
Air intake with check valve
Flyash intake and valve, chain operated
Rotary dustless unloader
Ash pit hopper
Sump or sewer
Ash conveyor in trench
Enclosures for airtight doors
Feeding hoppers (2-ft-sq grid)

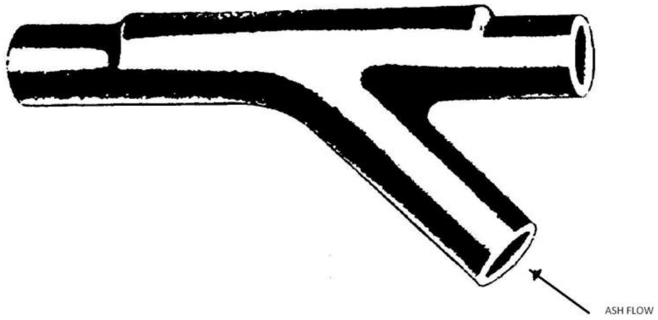
Vacuum pneumatic system. (Power *magazine.*)



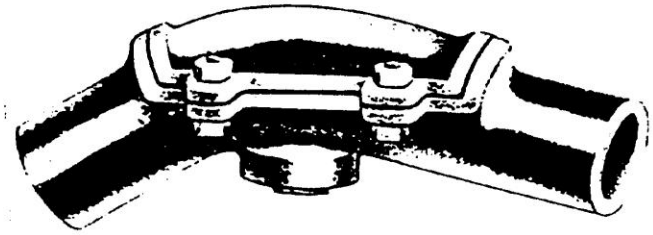
Pneumatically operated Slide Gate for controlling which section of hoppers the ash is collected from



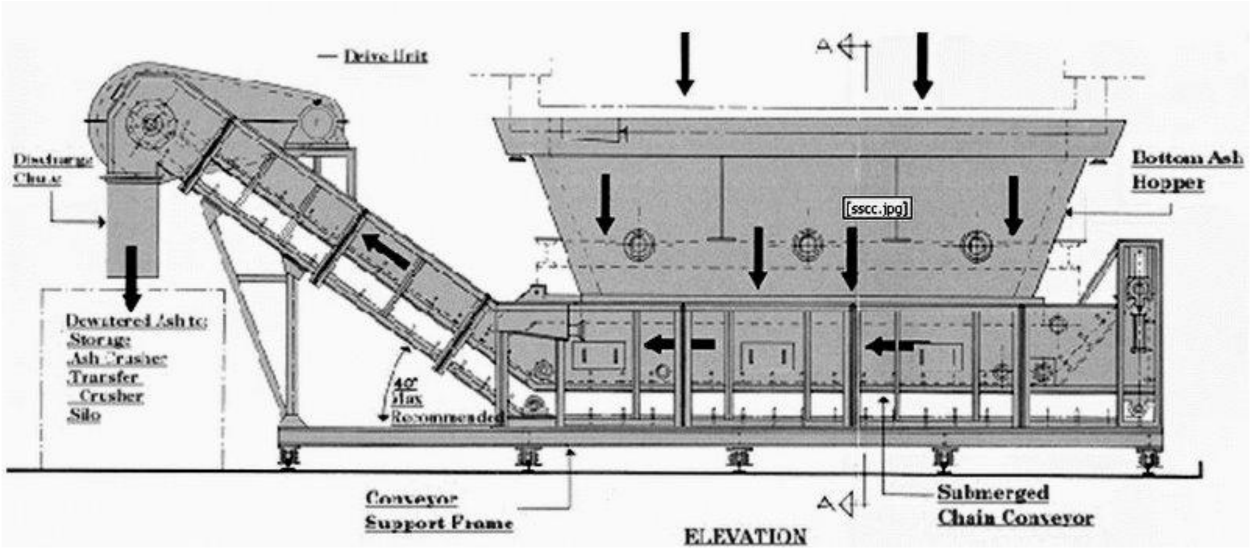
Flyash valve on the bottom of the hopper



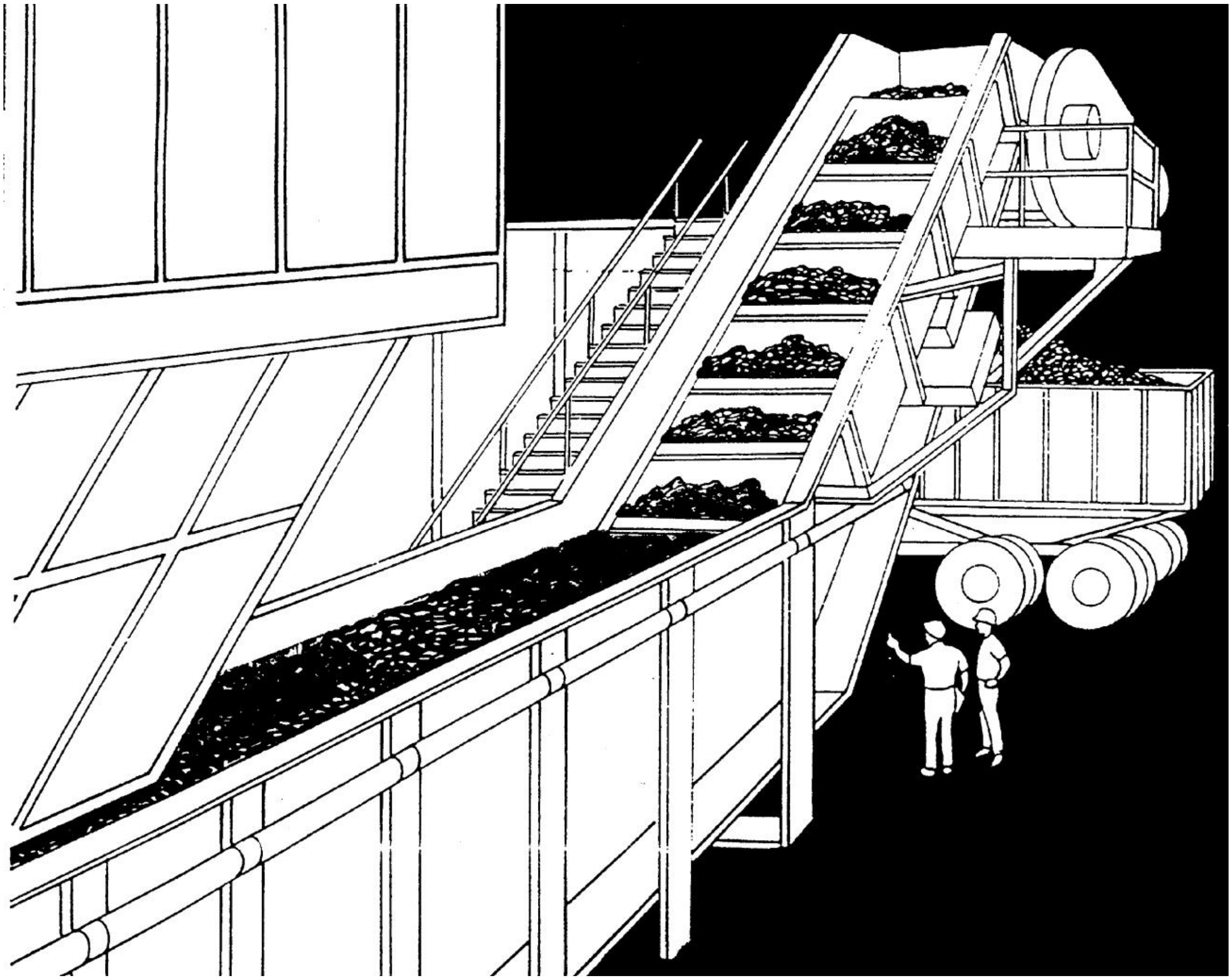
Ash piping has heavier sections where the flyash makes turns because of the abrasive qualities of the ash



Some ash piping has replaceable elbows to make repair easier



Submerged drag flight conveyor sits directly underneath the utility boiler furnace

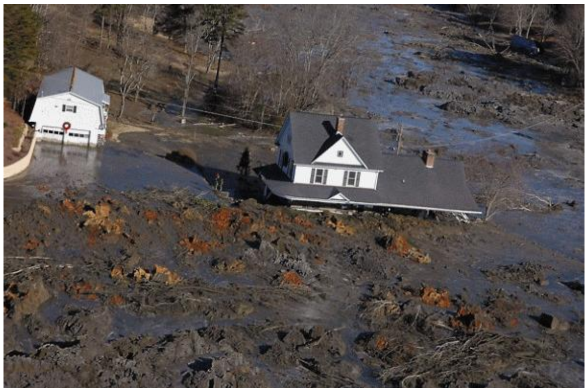


Submerged drag flight conveyor moves the wet ash from the bottom of the boiler to the truck

Ash silos with trucks loading up

Another tuck gets a load of ash

The ash is normally trucked to a landfill. Some flyash is used as a replacement for some of the Portland cement content of concrete.

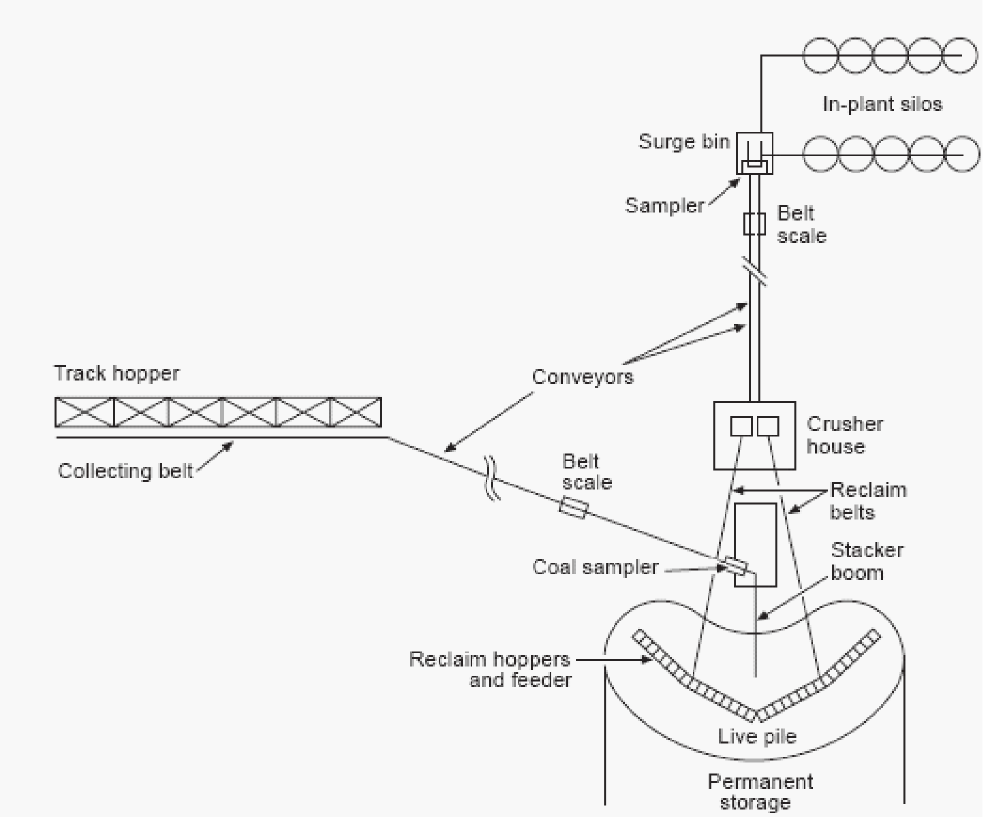


Sometimes flyash is pumped to a retention pond. If the retention wall breaks, as in the two pictures on the right, the 40 acre retention pond spread 3.1 million cubic feet of ash and flooded 400 acres at the Kingston Power Station.

What is a reclaim hopper?

It is part of the fuel supply system also called emergency reclaim. You can use heavy equipment to take coal from pile (bulldozer) and put into this hopper. It has a 7 foot wide belt to put 1500 tons an hour coal into system if everything else fails to supply the coal to the bunkers. It is used as a last resort.

Joe Grubb Notes



This is an overhead diagram showing a coal handling system. The rectangles with the X represents coal railcars. The conveyor belt is underneath the bottom dumpers. The coal is weighed on a belt scale as it goes to a radial stacker that swings back and forth to form a kidney shaped coal pile. The coal pile is over the reclaim hoppers. Bulldozers push the coal from the live pile to the longer permanent storage pile. The reclaim hoppers sit underneath the live pile. The coal is conveyed to the crusher house and then is conveyed across another belt scale to the surge bin where it is distributed to the coal silos inside the Powerhouse.

Anthracite coal weights 53.4 pounds per cubic foot. Bituminous coal weighs 52.8 pounds per cubic foot. With a separate pile of each coal weighing 1250 tons each, how many more cubic feet of bituminous coal would exist?

Anthracite pile = 1250 tons x 2000 lb/ton x 1 cubic ft./53.4 lb/cu. ft.
A.P. = 46,816.479 cubic ft.

Bituminous pile = 1250 tons x 2000 lb/ton x 1 cubic ft./52.8 lb/cu. ft.
B.P. = 47,348.484 cubic ft.

B.P. - A.P. = 532.005 cubic feet more bituminous coal.

Bituminous Coal burning on a grate

Chapter 4 Coal and its Combustion

What percentage of excess air should be used to ensure complete combustion?

EXCESS AIR

Coal…………….	10 - 40% at furnace outlet
Oil………………	8 - 15% at furnace outlet
Gas (natural) …..	5 - 10% at furnace outlet

Why is dew point of importance to an engineer?

The temperature gradient through the tube wall of an economizer is very small, and since the conductance of the inside wall is very high, the outside surface of the tubes is only a few degrees higher than the water temperature with no sulphur present in the flue gas, dew point is 120 degrees Fahrenheit but with only a small trace of SO3 dew point will climb to 300 degrees Fahrenheit or higher. Consequently some external corrosion may be expected when the temperature of the water is lower than the dew point of the flue gas. Careful watch of flue gas temperatures throughout the setting must be maintained to prevent corrosion from the sulphur trioxide and moisture forming sulfuric acid.

Kent's 12th edition page 7.34

How many BTU's does it take to raise one pound of a substance one degree Fahrenheit?

The specific heat of a substance is the amount of BTU's needed to raise the temperature of a substance one degree Fahrenheit.

The specific heat of Naphthenic base oils .45
Paraffin base oils is .425
Petroleum oils is .415

This means it takes about .4 BTU's to raise the temperature of these fuel oils, one degree Fahrenheit.

The specific heat of carbon or coke is .203, coal is .314.

The specific heats of gasses are given at constant volume or constant pressure.

Ethylene has a specific heat of .33 (volume) and .4 (pressure)
Natural gas is mostly methane and its specific heat is .45 (volume) and .593 (pressure.)
Hydrogen specific heat is 2.44 (volume) and 3.42 (pressure)
Blast furnace gas specific heat is .174 (volume) and .45 (pressure)

Croft, Practical Heat, page 77 & 213
Chemical Engineering Handbook, 5th edition, Perry & Chilton

Once the ignition point of a fuel has been reached, what must be added to ensure complete combustion?

When the combustible material reaches its ignition temperature, oxidation is accelerated, the process is called combustion. It is evident, therefore, that it is important to maintain the fuel and air mixture at a temperature sufficiently high to promote combustion. Air supply, mixing, and temperature determine the rate at which combustion progresses. In all cases an appreciable amount of time is required to complete the process.

Steam Plant Operation by Woodruff & Lammers, page 87

How are steam jets used to try to increase turbulence in the furnace?

Steam jets create a draft and increase the turbulence over the fire by direction the steam through a pipe on the side of the furnace and into the furnace in which it is strategically injected into the fire. The injected steam is introduced just over the fuel bed to cause turbulence and limit the smoking. The air or steam expanding through the larger pipe and the relatively lower pressure of the furnace is how the draft is effectuated. Though steam jets can bring about draft they are seldom the primary modes of draft for the boiler and are usually used in balanced draft settings. The operation of steam jets can be very helpful in reducing smoke when started just before smoking or sooting problems arise. This is important because once a smoking condition arises it is very difficult to control even with jets in operation. Great care must be taken when operation the steam or air jet. Similarly to operation a soot-blower the steam from a steam jet must not impinge on the waterwalls or the firebrick. This could possibly cut the tube or damage the refractory of the furnace. To operate the steam jet properly the correct amount of air or steam must be used so that the steam does not come in contact with the wall. Too much steam could also inhibit the combustion of the fuel and may cause the flame to lift.

Steam Plant Operation by Thomas Lammers, Herbert B. Lammers, and Everett B.
Woodruff, (New York: McGraw-Hill, Inc. 1984), pages 205 and 206
Steam Plant Operation by Woodruff and Lammers 8th edition page 340-341

What types of boilers would you find these steam jets in?

Steam jets are used to set up turbulence in the furnace to break up existing stratification and thus speed up the completion of combustion. These jets were found to be most effective when located in the bridgewall and directed forward to blow above and parallel to the fuel bed. Steam jets are used in conjunction with rear arches, which also aid in the combustion process, and are found in **spreader stokers and multiple-retort stokers**. Due to the fact that the jets increase turbulence, smoking will be reduced, and in the case of spreader stokers, the amount of flyash carryover can be reduced by as much as 50 percent.

Blue Combustion Engineering 9·21

Do these steam jets keep the boiler from smoking?

Steam jets have been used in boiler furnaces since the turn of the century. Early applications were of rather primitive design and not very effective in reducing smoke or soot. Steam jets primary function was to reduce smoke and soot by directing a jet of steam or air over the fire to create an environment which augments complete combustion. Over the years it has proved difficult to persuade the boiler operator to use the steam jets when a smoking condition presented itself in the furnace of the boiler.

Steam Plant Operation by Thomas Lammers, Herbert B. Lammers, and Everett B.
Woodruff, (New York: McGraw-Hill, Inc. 1984), pages 205 and 206

Extensive experiments have demonstrated that the best overall efficiencies are obtained when all the combustion air is introduced through the grates and the fuel bed, and when furnace turbulence is maintained mechanically by the use of steam jets without increasing the excess air. The preferred location of the steam jets is in the four corners of the furnace, in the same horizontal plane, about 3 feet above the grate and directed tangent to an imaginary circle near the center of the furnace. Steam jets applied in this manner frequently reduce the cinder carryover by 50 percent or more, while the visible smoke is reduced to less than one-third of that discharged when the jets are inoperative.

Blue Combustion Engineering page 5·15

Steam is a better cleaning agent than and can actually clean the soot off the tube surfaces when operated properly. Ninety percent of the steam jet applications are in chain grate, overfire or traveling grate furnaces because they are more forgiving to operate the steam jets in this type of boiler. In recent years the steam jets have been introduced into pulverized coal boilers.

One of the problems with the new ultra-low O_2 burners is that when you cut back on your excess air to extremely low levels, nitrates of oxide or NOX increase and excess air must be increased. Most of the research has been directed at the burner and turbulence around the burner. Not much has been done in the design of the furnace itself. Steam jets can be a critical part of furnace design and will play an important role in future emission law compliance.

Telephone conversation with Jim Spencer of Lipten Company. March 19, 1996 discussing steam jets and burner technology.

When burning oil, coal, or natural gas, which fuel takes the most oxygen to burn completely?

Coal.

It takes 2.67 pounds of oxygen to burn 1 pound of carbon to form carbon dioxide. This takes into account 10-40% excess air, which is needed to insure "complete" combustion. Fuel oil requires 3.54-3.76 pounds of oxygen, but only 8-15% excess air. Natural gas requires 2.51-2.63 pounds of oxygen with 5-10% excess air.

Kent’s 12th pages 2-05, 2- 06, 2-13

What causes draft in a stack?

A differential in pressure, usually between the atmosphere and the inside of the boiler setting.

A differential in draft is required to cause the gases to flow through a boiler setting. This required differential varies directly as the square of the rate of flow of gases. For example, when the flow is doubled, the difference in draft between two points in the setting will increase four times. A pressure in the furnace slightly lower than that of the atmosphere (draft) causes the air to enter, thus supplying the oxygen required for combustion. A draft at the boiler outlet greater than that in the furnace causes the products of combustion to circulate through the unit. The rate of flow or quantity of air supplied can be regulated by varying the draft differential.

Steam Plant Operation by Woodruff and Lammers 8th edition page 193

If fresh coal is added to a furnace, the most smoke would be eliminated by adding more O2 near the flame, in the retort, or nearer the stack?

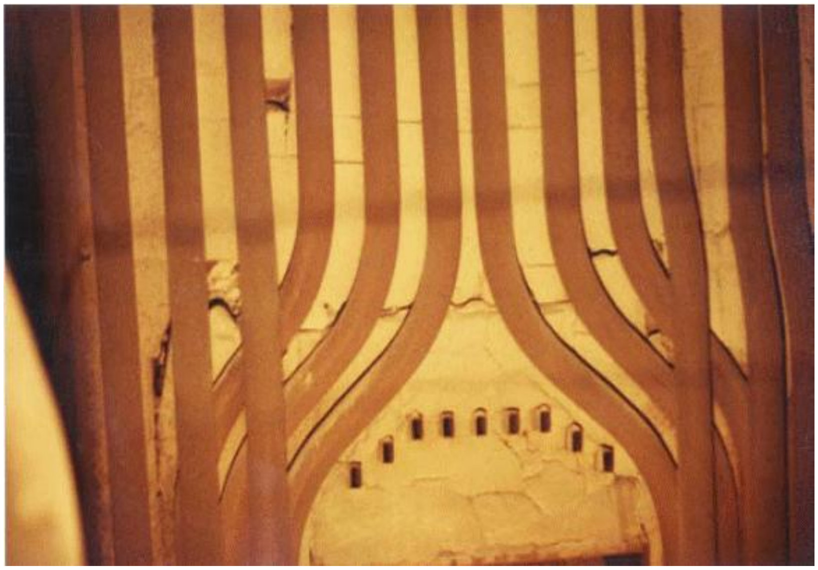
Near the flame.

Smoke is the result of combustible gases reaching the heating surfaces before complete combustion. These hydrocarbons and carbon monoxide must be burned as soon as possible for efficient combustion to take place. Air must be admitted above the fuel bed to burn these gases. The retort is only a means of delivering the coal to the fuel bed, and practically no air is introduced through it. Air added nearer the stack is not going to eliminate the smoke that has already passed through the boiler unit, although it may reduce the density of the smoke.

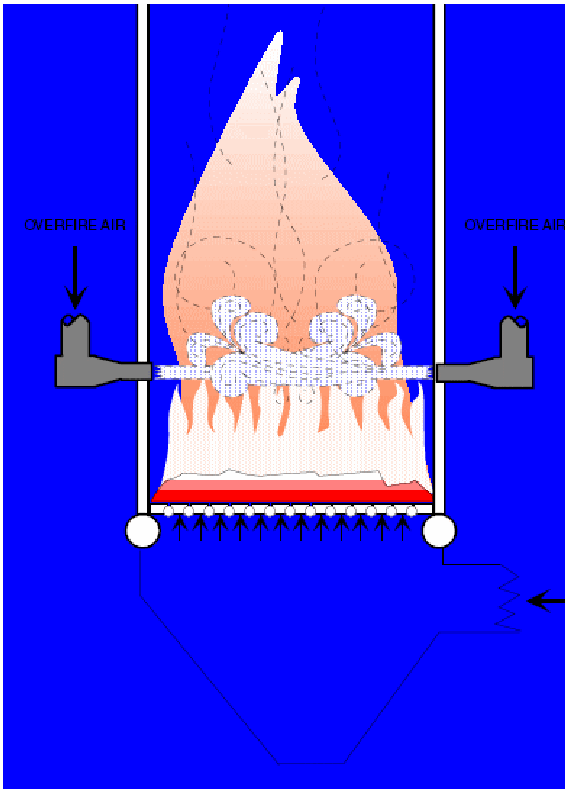
Steam Plant Operation by Woodruff and Lammers 3rd edition page 132

Immediately after introducing coal into a fire a great quantity of volatile matter is distilled, calling for a large amount of air to burn it

Railroad and Locomotive Engineering. Jan. 1888-Dec. 1891 page 88



Overfire air jets over the grates. Note how the boiler tubes have been bent around and under the other waterwall tubes to make room for the jets.



What factors must be thought out in the design of a new electrical generating plant?

The factors which exert the most influence on the selection of fuel-burning and steam-generating equipment are the following:

1. Fuel characteristics
2. Capacity and steam conditions
3. Space conditions
4. Cost
5. Individual preference

1. FUEL CHARACTERISTICS

a. long term availability
b. backup fuel in case the primary fuel supply is interrupted
c. multiple fuel burners
d. Natural gas is piped direct from supplier’s mains; as a result, there are no handling costs. Furthermore, there is no refuse resulting from its use. Storage of gas is impractical. If the supply of gas fails, a standby fuel must be used.
e. The cost of burning fuel oil is usually low. It consists of storage, pumping, heating and atomization of the fuel oil, and maintenance of the equipment. With heavy fuel oil, heating is a considerable item, particularly in cold weather. Even though the ash content is very low, deposits collect on the heat-absorbing surfaces throughout the unit. These usually contain a large portion of the fuel oil's sulphur content and their acid nature will cause severe corrosion in the economizer, air heater, induced-draft fan, and breeching connection. This corrosion can be minimized only by frequent cleaning. The cost of such cleaning and maintenance is properly charged to the burning of fuel oil.
f. The cost of burning coal should properly include maintenance equipment, as well as all handling charges from railroad cars to storage to steam-generating unit, together with the cost of soot blowing and ash disposal. The average cost of burning coal in the United States, exclusive of fixed charges, is approximately 5% of its cost. For fuel oil, this cost is approximately 1.5% of the equivalent coal cost, and for natural gas about 0.5%. Annual fixed charges include interest on the investment, amortization, insurance, taxes and other similar items.

CAPACITY AND STEAM CONDITIONS

Capacity requirements determine the size and type of equipment to be used. Equipment selection is dependent on steam conditions; namely, steam pressure, steam temperature, and temperature of the feedwater entering the unit.

DESIGN PRESSURE

Capacity requirements determine the megawatts. Megawatts determine the size of the turbine generator. The turbine generator determines the steam conditions, superheat temperature and the operating pressure. The pressure at which the boiler operates, the amount of steam needed, and the fuel determines the size of the furnace. The amount of piping required to supply the required steam and the pressure drops through the piping are then calculated. High pressure steam-generating units of the utility type can be designed for pressures up to 2750 psi with natural circulation, and for steam temperatures of 1050 degrees Fahrenheit and above. With controlled forced-circulation, the design pressure can be increased to about 3000 psi.

STEAM TEMPERATURE

On large steam-generating units the superheater design is completely developed before the design of the boiler convection surface can be determined. Steam superheat temperatures are limited by the ability of the superheater tubing to handle those temperatures.

FEEDWATER TEMPERATURE

Boilers equipped with economizers are affected by feedwater temperatures, since the proportioning of boiler and economizer surface is varied with variations in feedwater temperature. Economizer temperatures should be high enough that moisture does not condense and corrode the outside of the tubes and low enough that the economizer does not steam, unless designed to do so.

HEAT - RECOVERY EQUIPMENT)

In general, the amount of boiler surface supplied is less when heat-recovery equipment is used than when it is omitted.

The choice between air heaters and economizers is determined by the following factors:

a. Allowable maximum air temperature, dependent on type of fuel-burning equipment used.
b. Boiler pressure and feedwater temperature as affecting allowable absorption in economizer.
c. Arrangement and amount of heating surface required.
d. Temperature of gas at boiler outlet.

When selecting an air heater, the following factors should be evaluated to determine the relative values of the different types under consideration:

a. Initial cost - includes any difference in cost of fans, ducts or changes to setting.
b. Space occupied.
c. Draft loss.
d. Operating and maintenance costs.
e. Life of surface and cost of surface replacement.
f. Type of fuel used.

In the large utility type designs, the heat-recovery equipment almost always includes both economizers and air heaters, in order to obtain the highest efficiencies which can be economically justified 88 to 90 %.

SPACE CONDITIONS:

Space conditions are determined by the equipment selected. Site selection should reflect this. Factors to consider are:

1.The steam-generating capacity
2. The degree of heat recovery
3. The required furnace volume for the combustion conditions
4. The length of the building depends upon the boilers, coal bunkers, breechings and ash-handling equipment. The width is determined the depth of all the equipment and adequate space for maintenance and replacement of equipment and replacement of boiler and superheater tubes.

COST

The conditions that characterize a base-load plant would justify a capital investment sufficient to provide a highly-efficient fuel-burning system, watercooled furnace walls, high-pressure boiler, high-temperature superheater, heat-recovery equipment, induced-draft fan, and maximum refinement of auxiliaries.

Frequently, the final selection of a steam-generating unit narrows down to a choice between two designs whose relative costs are not more than 15 to 20% apart. In a high-load-factor plant, the value of the fuel burned during the useful life of the equipment may represent as much as three hundred times this difference in initial investment. Even a small advantage in reliability, efficiency or flexibility would give economic justification for the relatively small additional capital cost necessary to provide the better unit.

INDIVIDUAL PREFERENCE

Sound judgment and the experience of others should be used to determine the brands of equipment used. The financial soundness of the company is a major consideration.

Uniformity of equipment has a strong appeal. There may be definite merit in a preference for equipment of the same design as that already installed. The plant organization is familiar with its operation, and perhaps the plant itself was originally designed for the type of equipment installed and is not well suited to other types without costly building changes. On the other hand, for many plants, the advantages to be gained by the use of more modern designs far outweigh the reasons for duplicating equipment. Often, modern designs will provide more capacity in the same space with higher efficiency, and at a reduced cost for labor and maintenance. A well-founded individual preference should be respected and accorded full consideration. However, mere personal prejudice should be corrected so that it does not jeopardize the value of an investment for plant extension or plant betterment.

Blue Combustion Engineering Chapter 24, pages 1through 23

River Rouge Detroit Edison Plant showing space requirements for the building and fuel storage.

What does Dulong's formula concern?

The heating value of fuels

Kent’s 12th page 2-04

When the percentage of carbon, hydrogen, and sulfur in the fuel are known, the heating value can be approximated by using DuLong's formula. The percentages of carbon, hydrogen, and sulfur are determined by the ultimate analysis, usually performed by a chemist in a laboratory. The more preferable method of determining the heating value of a fuel is by actually developing and measuring the heat. This is accomplished by completely burning a carefully weighed sample of the fuel in a calorimeter. The heat produced causes a temperature rise in a known quantity of water. The temperature rise is indicative of the heating value of the fuel.

DuLong's formula; Heating value, Btu/lb of fuel = $14{,}540\,C + 62{,}000(H - 1/8\,O) + 4050\,S$

where C = carbon;
H = hydrogen; and
S = sulfur

What is smoke?

Smoke is unburned carbon particles of extremely small size, 0.001 to 0.14 microns.

Kent’s 12th edition page 7-91

What causes smoke?

Smoke is produced if:

a. Air supply is insufficient for complete combustion.

b. Air and combustible gases are not thoroughly mixed.

c. Furnace temperatures drop below the ignition point of the gases.

d. Combustion space is too small, preventing proper mixing of air and gases, and allowing gases to come into contact with cool boiler surfaces they are ignited or fully burned.

Higgins "Boiler Room" Q. & A.'s page 73

How big is one particle of smoke?

From .001 micron to .25 micron

.25 micron = .00001 inch. That is one/one hundred thousandth of an inch, or 4 zeros before the number 1. To remember it, 4 fingers equal zeros and the thumb is the number 1

Kent’s 12th page 7-91
Detroit Edison Steam Course "Boiler Operations" page 6

Why is smoke-free combustion so important?

Smoke is formed from the tarry distillation products of coal, which escape before combustion is complete. The more efficiently and completely it is burned and the more efficiently the heat from this burning is used, the more effective will be the process. As the amount of volatile matter in the coal decreases, the quantity of tar evolved from the coal also decreases, reducing the tendency to smoke. High stack gas temperatures and a high percentage of combustible material in the ash are a direct indication of the lack of efficiency and economy. Fuel is purchased on the basis of the number of BTU per pound the fuel contains. It is the power engineer's job to make the best use of as much of this heat as possible.

Detroit Edison, Fuels and combustion page 19

What are soot and smoke indicators of?

Soot and smoke are indicators of incomplete combustion.

How are soot and smoke best controlled?

Other than the design of the furnace, the three most important factors for complete combustion are **time, temperature and turbulence**.

The fuel must remain in the combustion zone long enough for the combustion to be completed. The temperature of the fuel must be maintained high enough for continued burning, and the turbulence is necessary for the proper mixing of the fuel and air. In addition to this, turbulence in the combustion zone provides a longer path for the fuel to traverse and this in turn provides more time for the completion of the combustion process. Turbulence also provides a greater gas velocity, and this aids in stripping away the gas film from the solid carbon to expose new surfaces for gas formation.

Detroit Edison Steam Course, Fuels and Combustion

How would you correct a smoking condition?

To prevent smoke formation, the air supply must be sufficient for complete combustion. Air and gases must mix thoroughly. Keep furnace temperatures above the ignition temperature of the gases. There must be ample combustion space and proper baffling, where necessary, to mix air and gases and guide them on the proper path, Therefore:

a. Increase air supply to the furnace or reduce fuel supply.

b. Increase the over-fire air, tertiary air or cinder reinjection air to create turbulence.

c. Increase the preheated air temperature.

d. Supply fuel with less inherent moisture.

e. Install proper baffling.

f. Increase the size or redesign the furnace.

Boiler Room Questions & Answers by Alex Higgins page 73

What is the amount of CO_2 found in perfect combustion of Bituminous Coal?

18.6% CO_2, by volume (dry basis), is found in perfect combustion of Bituminous coal.

Kent's 12th Edition Table 1 p. 2-05

What is a good CO_2 reading for a good grade of Bituminous coal?

15% CO_2 is a good reading for a good grade of Bituminous coal.

Detroit Edison Steam Course Fuels & Combustion page 32

If the excess air is reduced from the optimum, what will happen to the CO_2 reading?

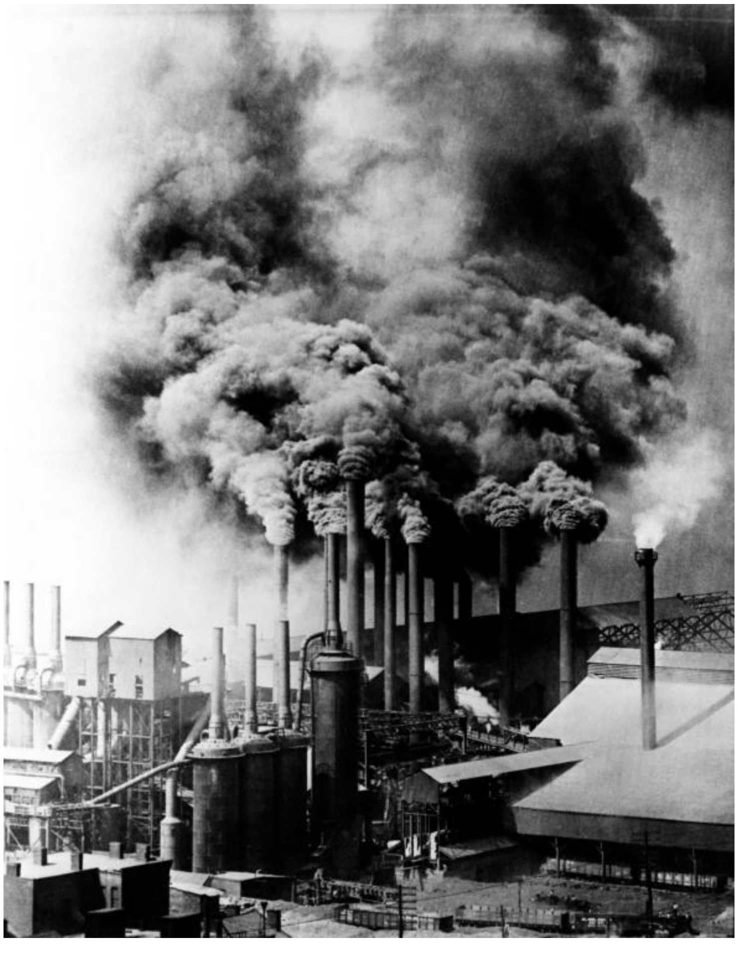
If the excess air is reduced from the optimum, the CO_2 percentage will fall and the CO percentage will rise. Conversely, If the excess air is increased beyond the optimum the CO_2 will fall from dilution with too much excess air. Maximum CO_2 readings are obtained with the optimum excess air, known as stoichiometric combustion.

What are the three methods of feeding coal that burns on a grate? Give an example of each:

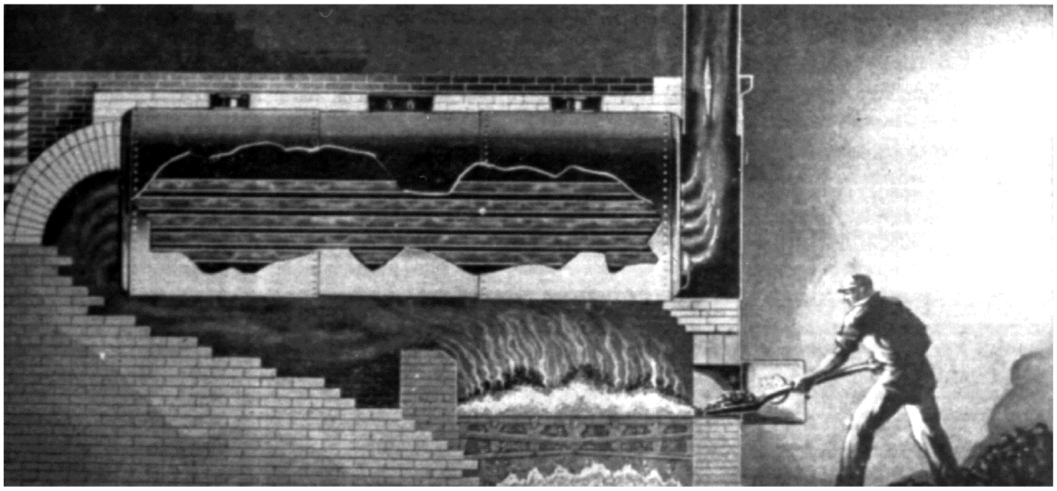
1. Overfeed method - hand firing and spreader stoker
2. Frontfeed method - chain grate and traveling grate
3. Underfeed method - single and multiple retort underfeed stokers

Blue Combustion Engineering page 2·23

Pittsburgh in its heyday



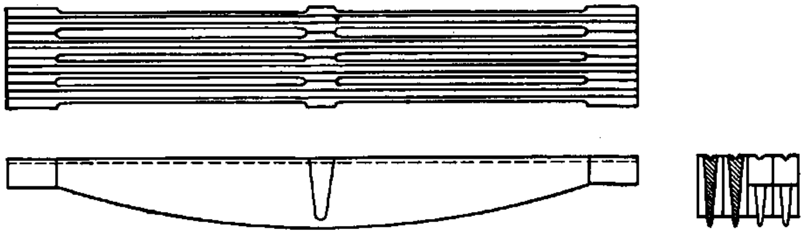
Chapter 5 Hand Firing Coal



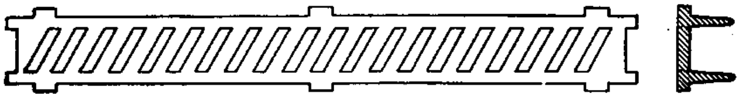
What size are the holes are in a hand fired grate?

The width of the air space should be as wide as possible without permitting coal to pass through. This width depends upon the kind and size of coal used, and ranges from 1/8 to 1/2 of an inch. The total area of the openings for air, when burning coal, varies from 20 to 50% of the total grate area. Grates intended for burning bituminous coal have air opening equal to 40% of the total grate area (due to the bridging action of a caking coal) and for anthracite coal 20%. There is 300 openings per square foot.

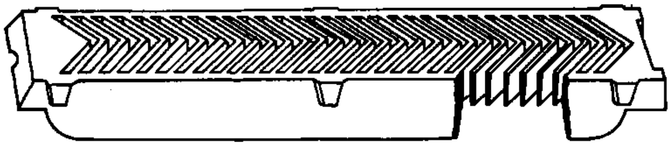
Steam Plant Operation by Woodruff and Lammers 3rd. edition page 132



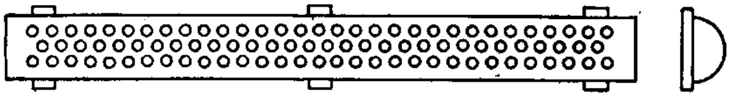
Plain grate bar.



Tupper grate bar.



Herringbone grate bar.



Pinhole grate bar.

STARTING A HAND FIRED COAL BOILER

1. Cover grate with coarse coal, then fine coal to 3 or 4 inches

2. Cover coal with a layer of wood and shavings

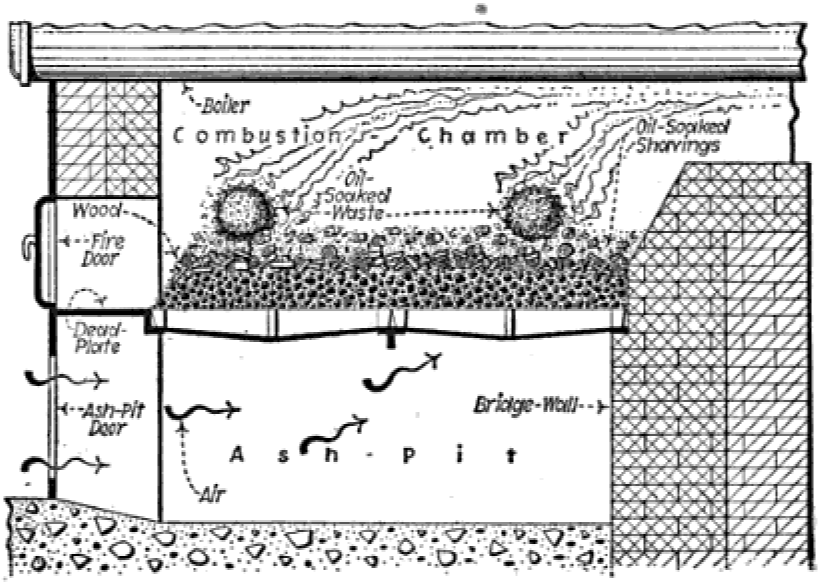
3. Place oily rags on the wood and ignite

4. Partly open the stack damper and the ashpit door to allow air circulate up from the ashpit through the fuel

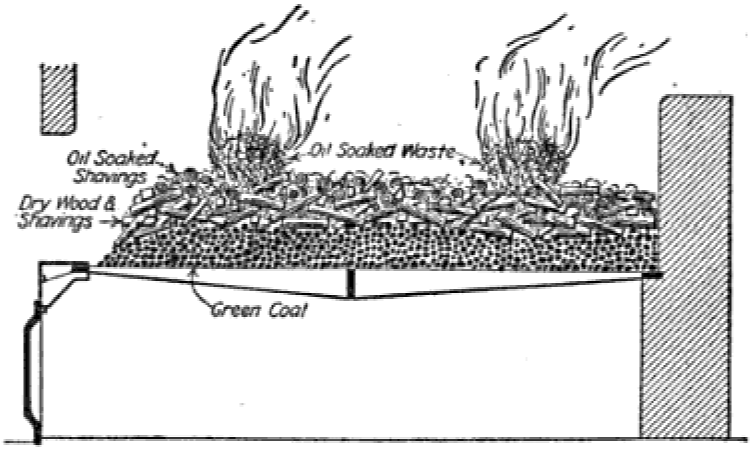
5. Volatile gasses from the coal must pass up through the burning matter and will be burned and reduces smoke

6. Coal should be added only after the entire bed is burning

Steam Plant Operation by Woodruff and Lammers 4th edition page 146



Starting a fire with soft coal in hand-fired furnace.

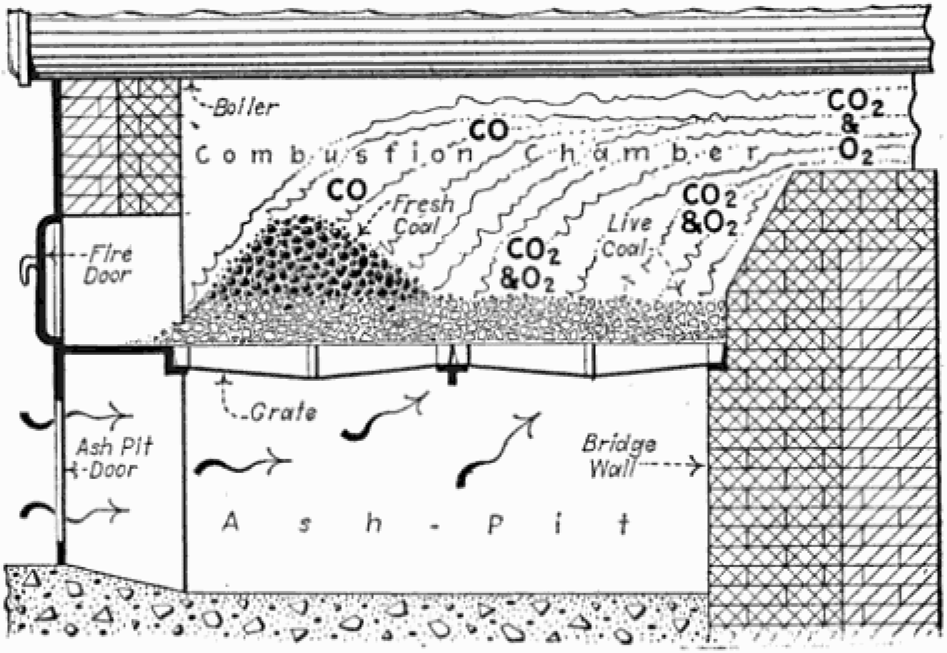


THREE METHODS OF HAND FIRING COAL

COKING METHOD

1. Place fresh coal on the dead plate at the front of the boiler and allow the gasses to be distilled from the coal before pushing the coal with the hoe onto the grates to finish burning

2. This does not work if using a caking coal

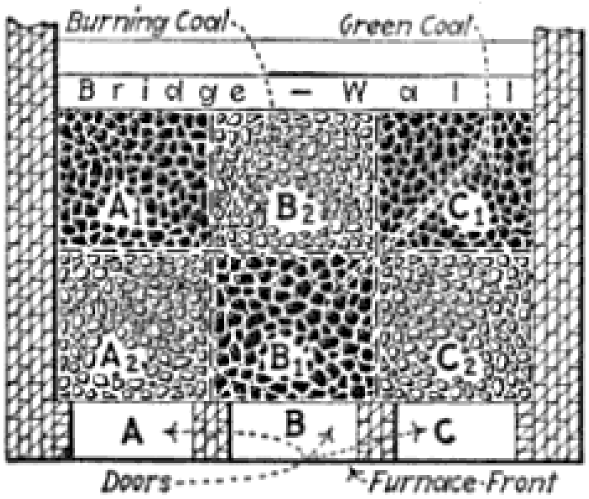


The coking method of firing.

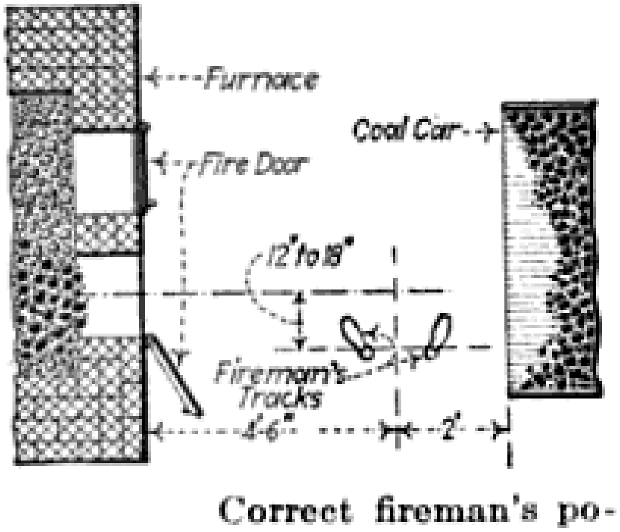
ALTERNATE METHOD

1. Throw fresh coal on one side of the furnace and allow the burning coal on the other side to distill off the gasses

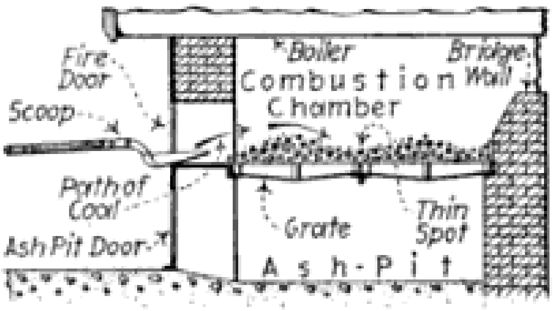
2. The disadvantage is that smoke may be produced if the volatile matter is distilled off too rapidly to burn completely



A method of alternate firing.



Correct fireman's position for good firing.



The end of throw in scooping coal into furnace.

SPREADING METHOD

1. Throw fresh coal evenly over the entire bed of coal in small amounts

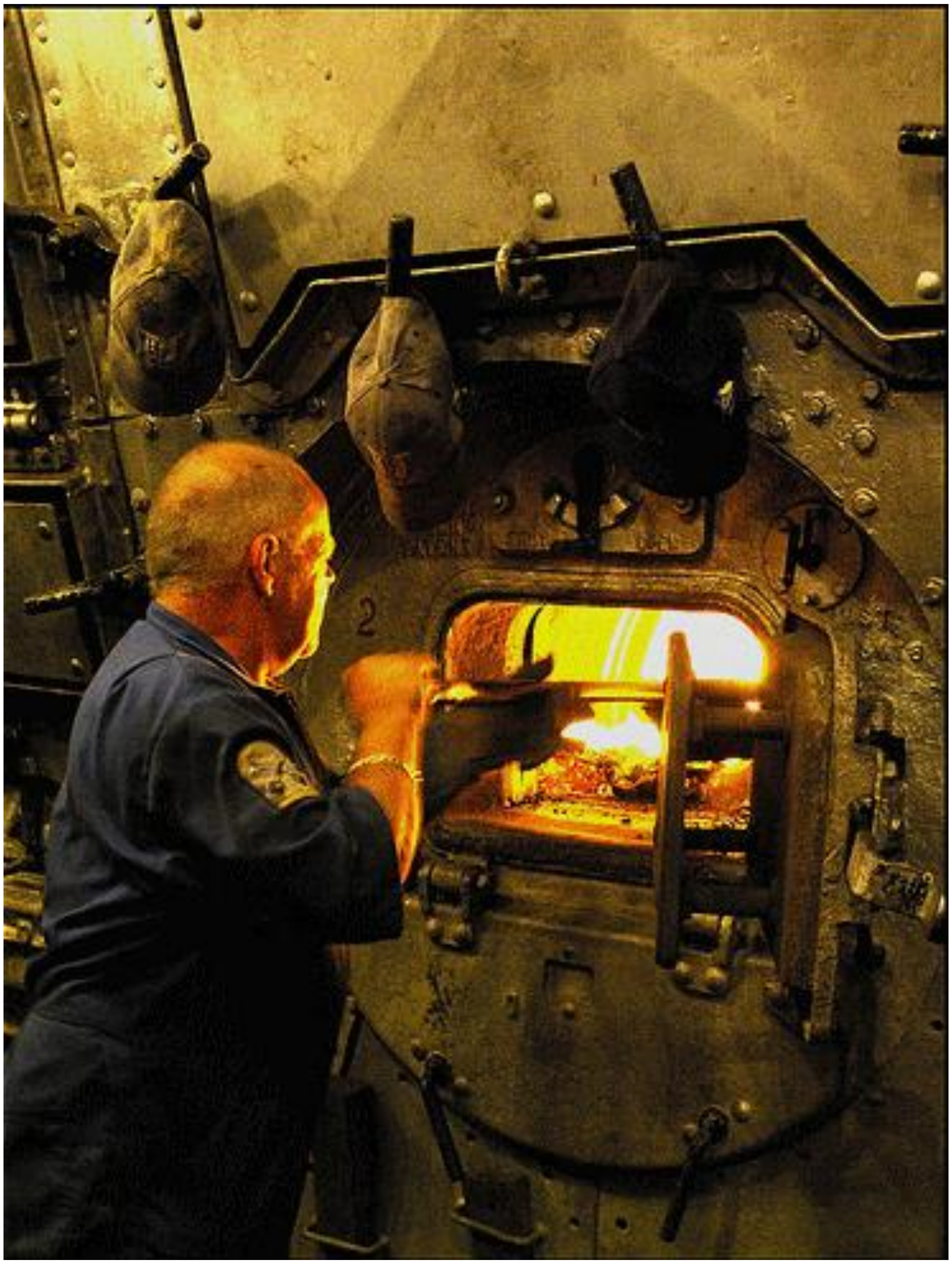
2. This method increases clinkering of the coal because the ash is exposed to the heat of the burning fuel

3. Caking coals will form a surface crust and cause unequal distribution of air

Steam Plant Operation by Woodruff and Lammers 4th edition page 146-147

4. The fireman that "fires little, fires often, and fires quick" makes less smoke.

Railroad and Locomotive Engineering Jan. 1888-Dec. 1891 page 88



To maintain a fire what must the operator do?

When necessary, but preferably at scheduled times when the load is light or before peak loads. The fire should be cleaned as quickly as possible without creating holes in the fire. This is to prevent cold drafts from entering the furnace. Firing should not be heavy immediately after cleaning.

Detroit Edison Steam Course "Boiler Operations" page 6 Q. #27

CLEANING THE FIRE

1. Using the slice bar, wing the live coals onto the right side of the grate

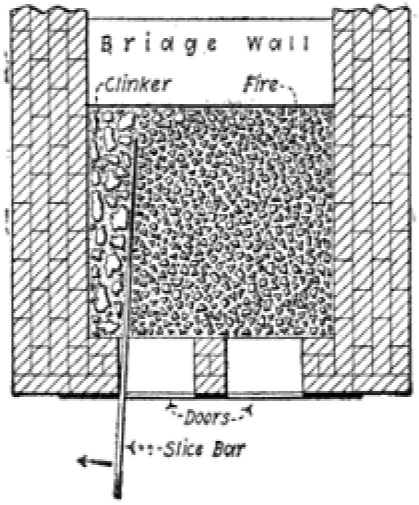
2. Pull the ash and clinkers out the front of the firing door from the left side of the grate

3. Wing the live coals onto the left side of the grate

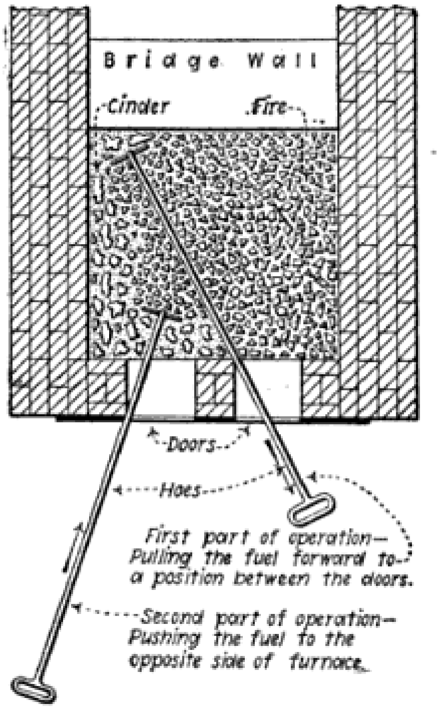
4. Pull the ash and clinkers out the front of the firing door from the right side of the grate

5. Spread the burning coal evenly over the grate and add fresh coal in one of the three methods outlined above

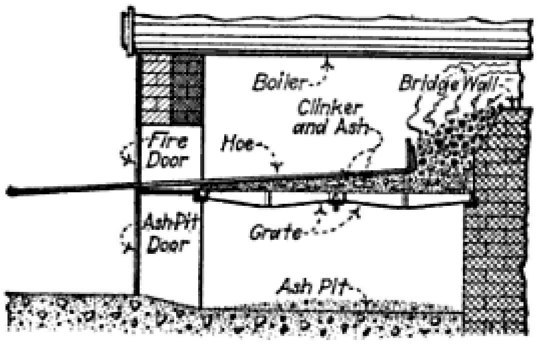
Croft Boilers page 227



Side method of cleaning with slice bar.


Bridge Wall
Cinder
Fire
Doors
Hoes
First part of operation— Pulling the fuel forward to a position between the doors.
Second part of operation— Pushing the fuel to the opposite side of furnace.

Side method of cleaning with hoe.



Front-to-rear method of cleaning fire.

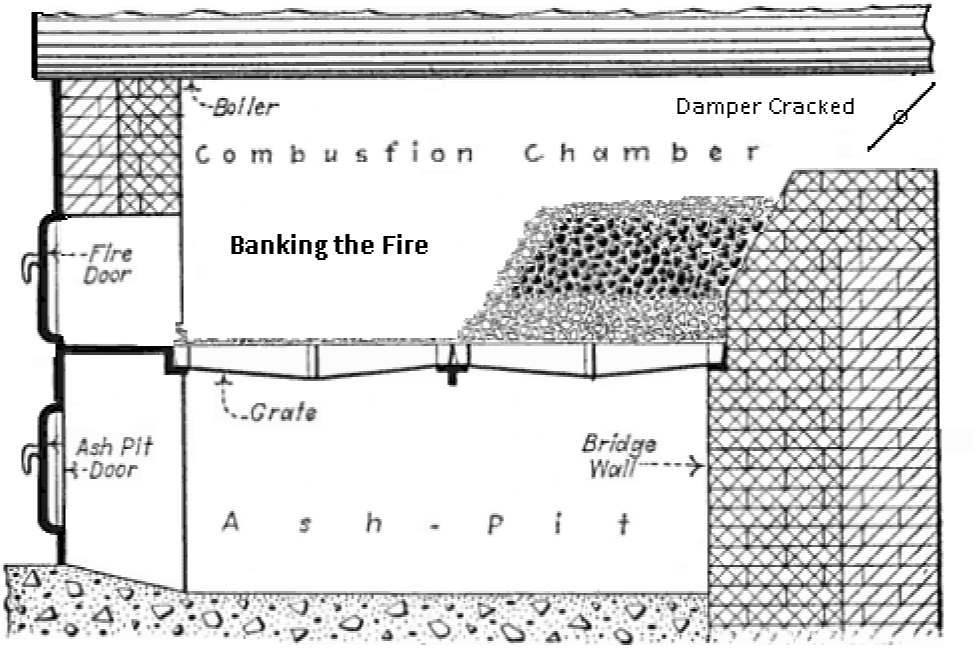
BANKING THE FIRE

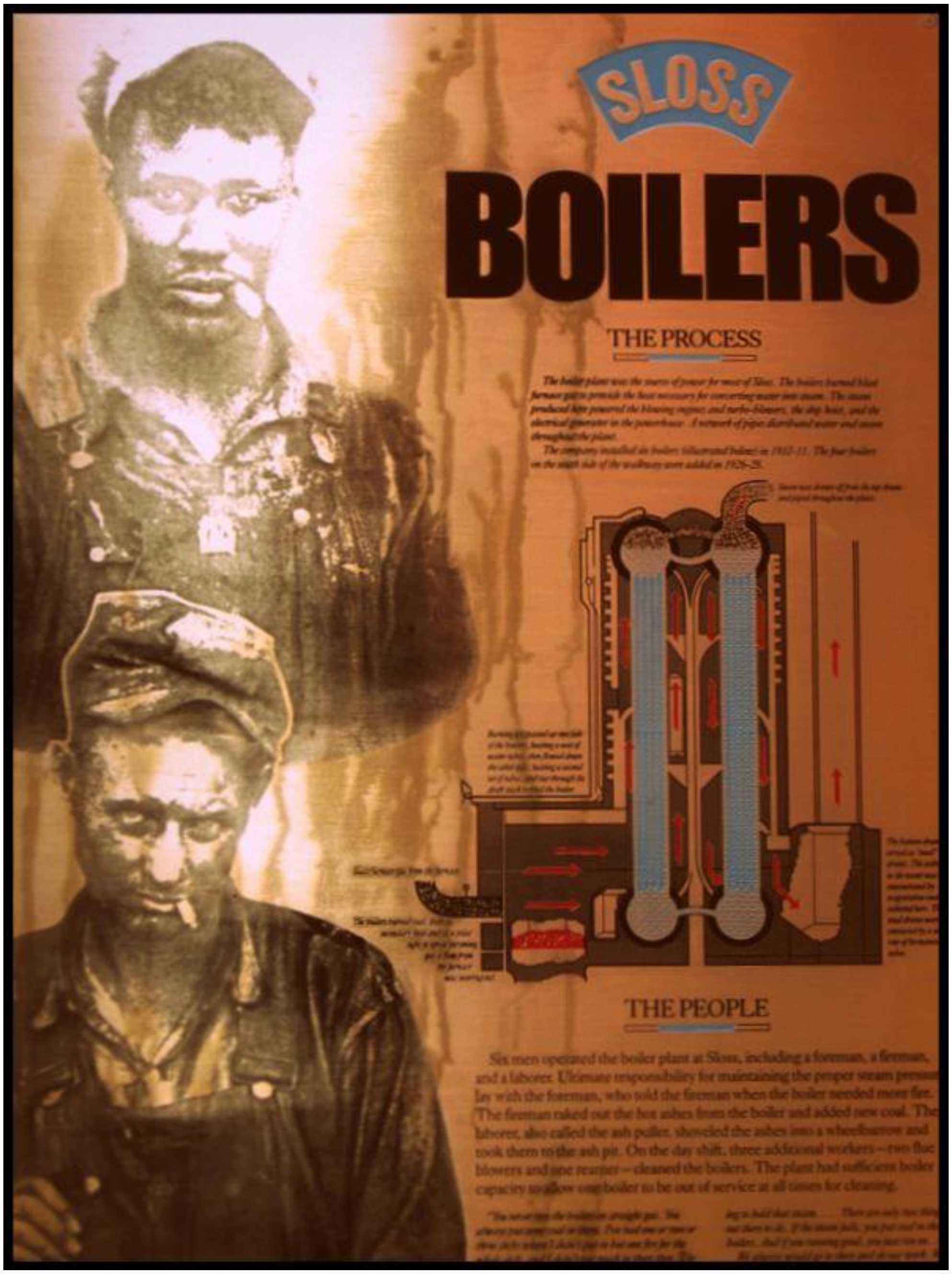
1. Let the fire burn down

2. Push the coal back against the bridge wall

3. Cover the coal with ashes

4. Close the firing and ashpit doors and crack the damper





SLOSS

BOILERS

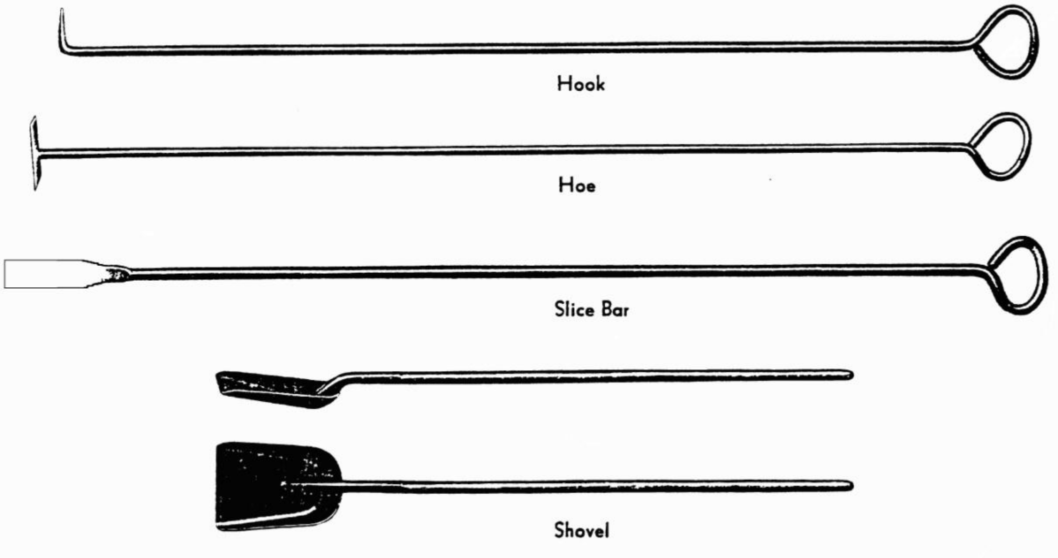
THE PROCESS

The boiler plant was the source of power for most of Sloss. The boilers burned blast furnace gas to provide the heat necessary for converting water into steam. The steam produced here powered the blowing engines and turbo-blowers, the skip hoist, and the electrical generator in the powerhouse. A network of pipes distributed water and steam throughout the plant.

The company installed six boilers (illustrated below) in 1910-11. The four boilers on the south side of the walkway were added in 1926-28.

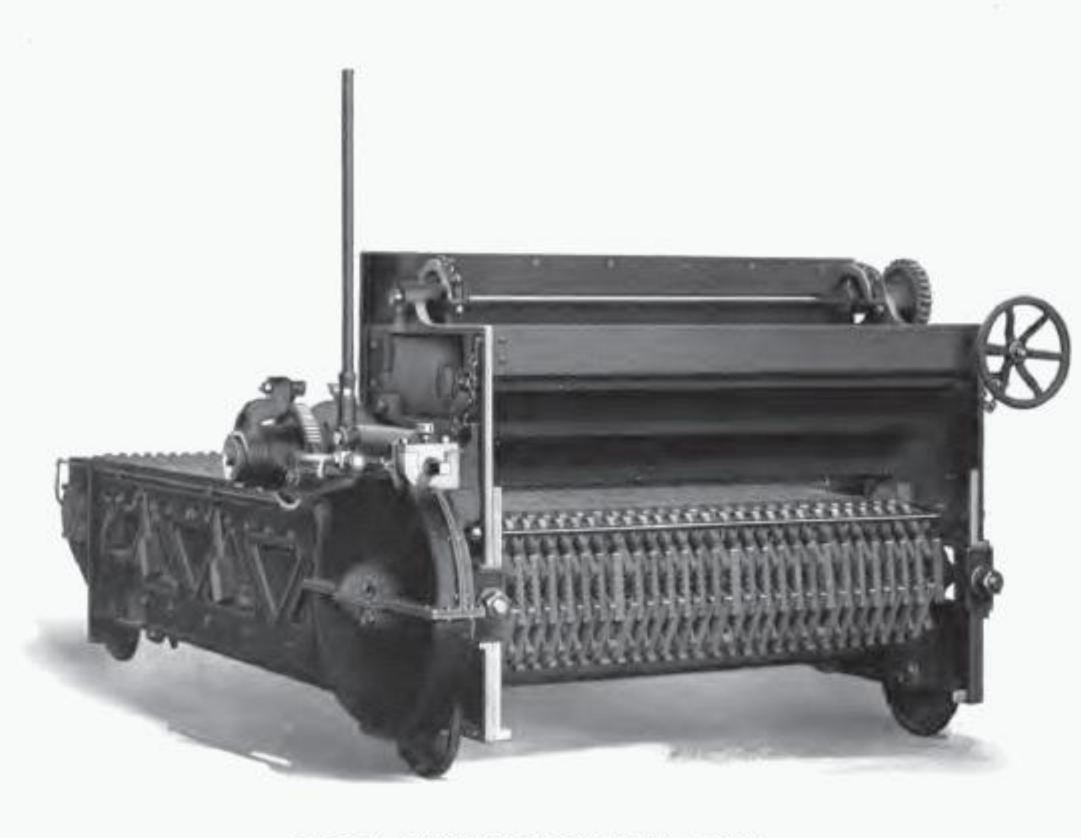
THE PEOPLE

Six men operated the boiler plant at Sloss, including a foreman, a fireman, and a laborer. Ultimate responsibility for maintaining the proper steam pressu lay with the foreman, who told the fireman when the boiler needed more fire. The fireman raked out the hot ashes from the boiler and added new coal. The laborer, also called the ash puller, shoveled the ashes into a wheelbarrow and took them to the ash pit. On the day shift, three additional workers—two flue blowers and one reamer—cleaned the boilers. The plant had sufficient boiler capacity to allow one boiler to be out of service at all times for cleaning.

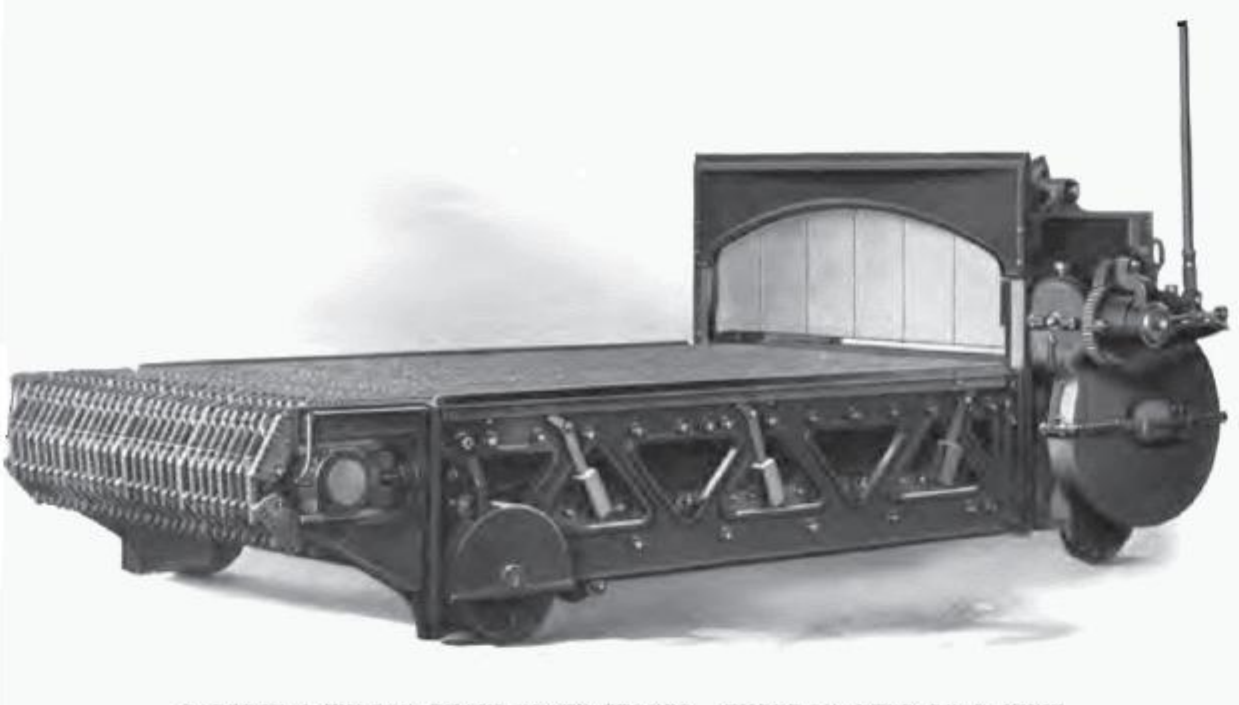


Hand firing tools and the Sloss hand firing crew waiting for that new chain grate stoker.

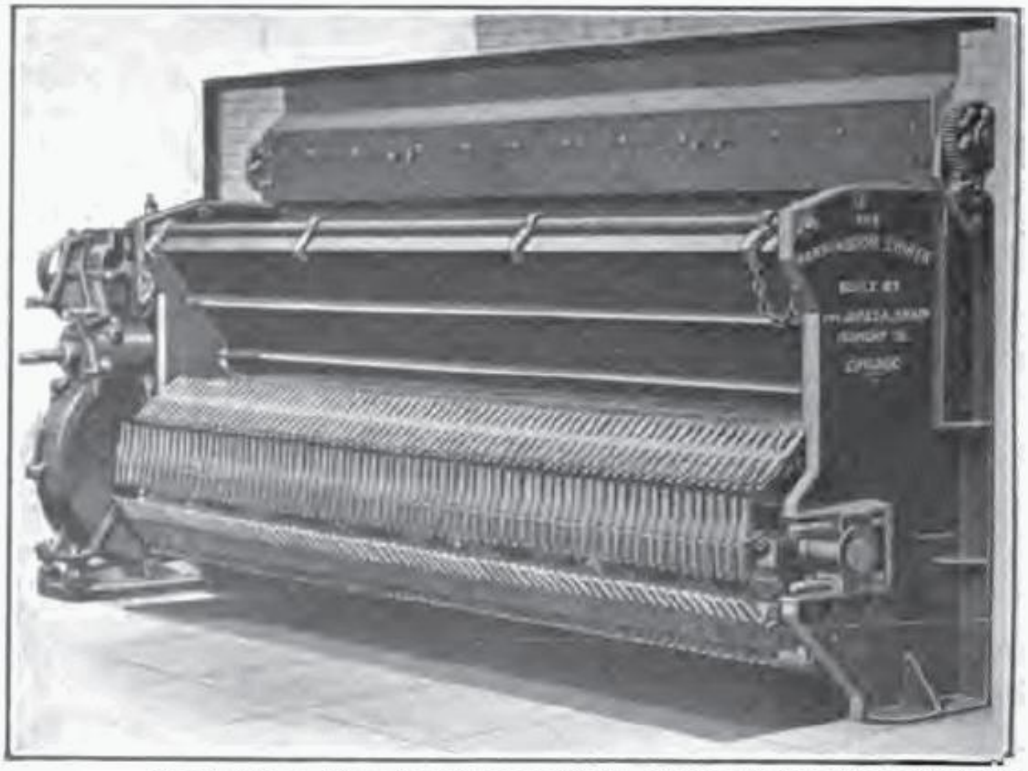
Chapter 6 Chain Grate Stokers and Traveling Grate Stokers



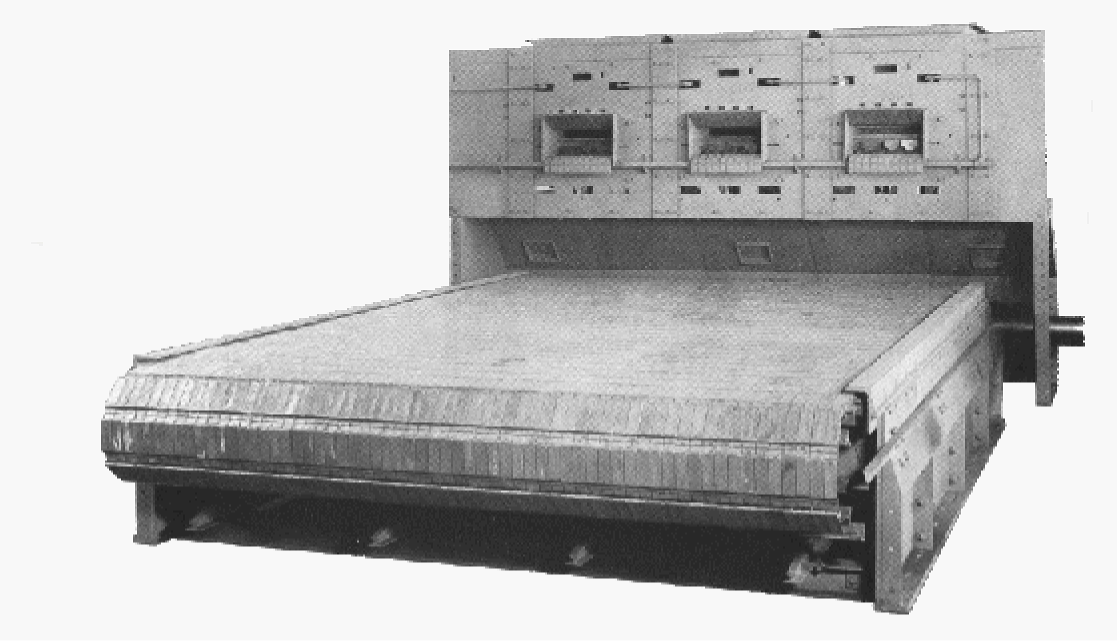
BABCOCK & WILCOX CHAIN GRATE STOKER



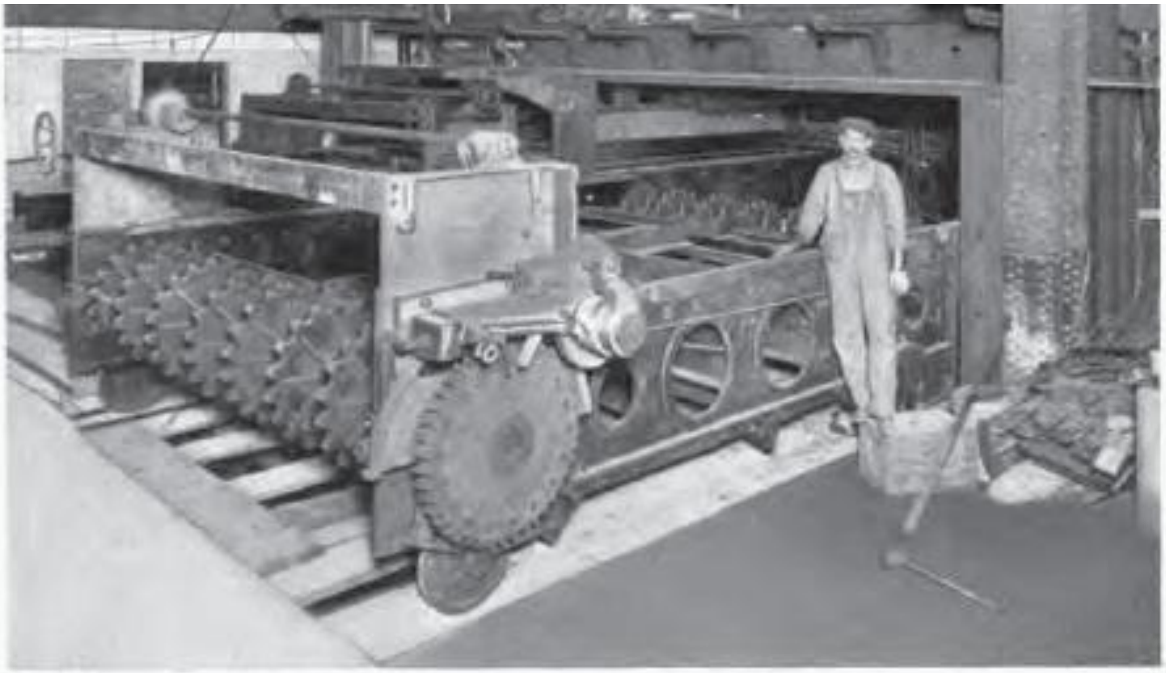
BABCOCK & WILCOX CHAIN GRATE STOKER. THREE-QUARTER REAR VIEW



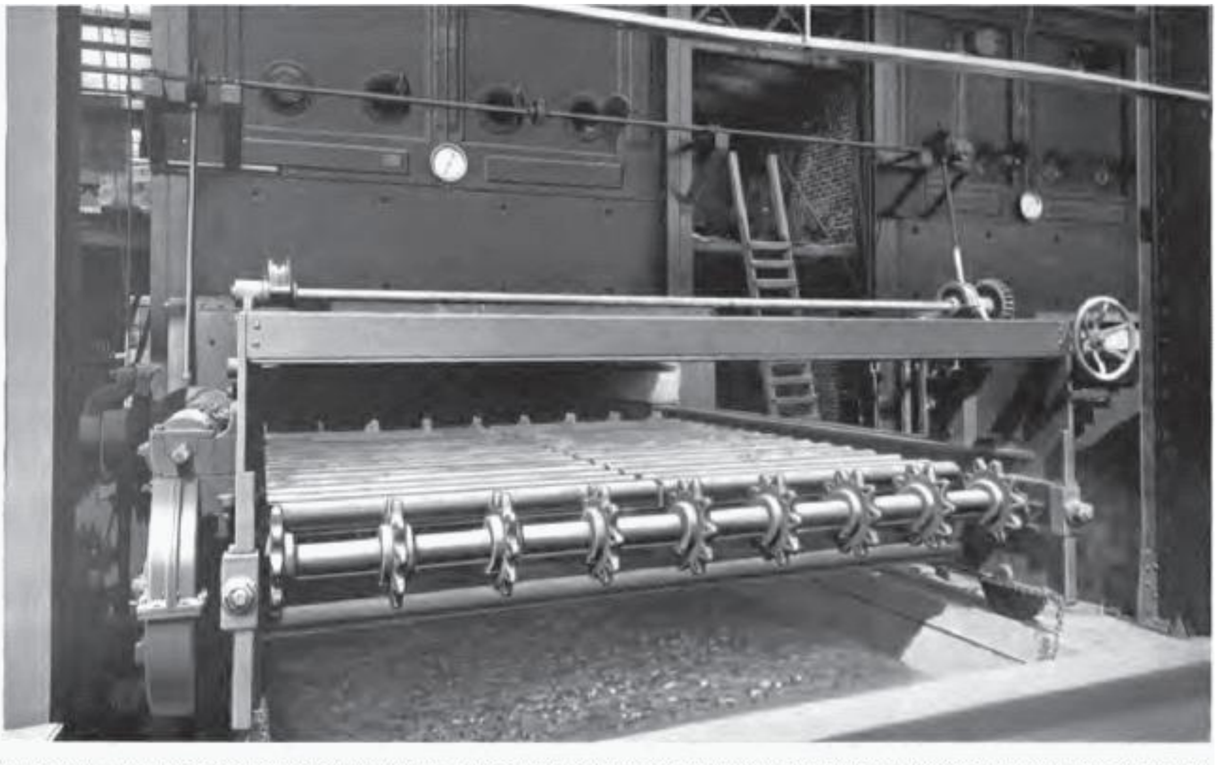
Front View, Showing Hopper Parts of Harrington Forced Draft Traveling Grate Stoker.



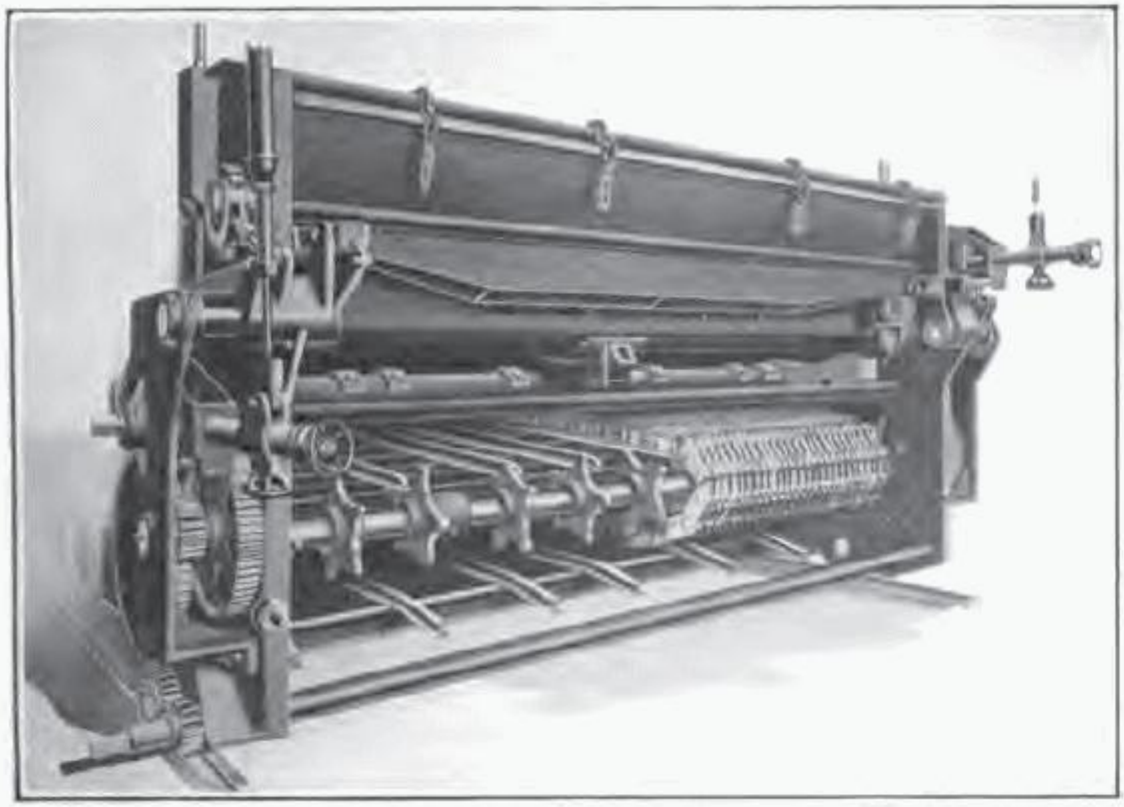
Furnace rear view of the traveling grate stoker. Notice how the chain grate uses individual links while the traveling grate uses a series of grates with holes in them. The individual grates form a section along the width of the stoker.



TWO BABCOCK & WILCOX CHAIN GRATE STOKERS IN COURSE OF ERECTION WITH A 1220 HORSE-POWER BABCOCK & WILCOX BOILER AT THE FISK ST. STATION OF THE COMMONWEALTH EDISON CO., CHICAGO, ILL.

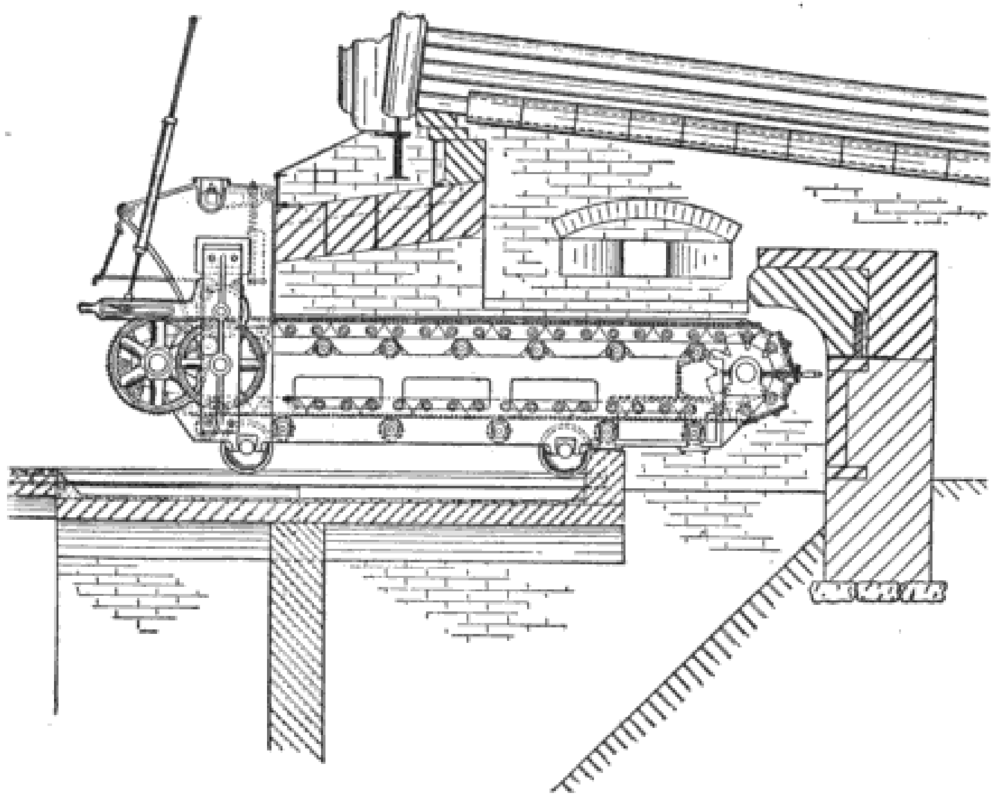


BABCOCK & WILCOX CHAIN GRATE STOKER IN COURSE OF ERECTION SHOWING STOKER BEFORE LINKS ARE IN PLACE



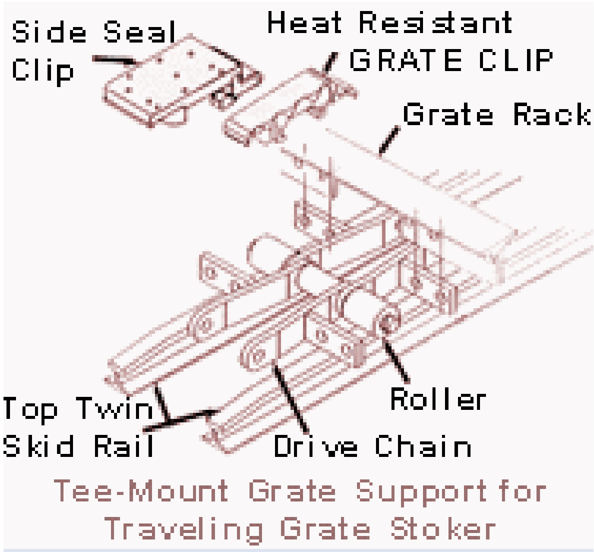
Front View Green "L" Type Chain Grate Stoker.

The Green Chain Grate Stoker showing how the chain conveyor is attached to the sprockets

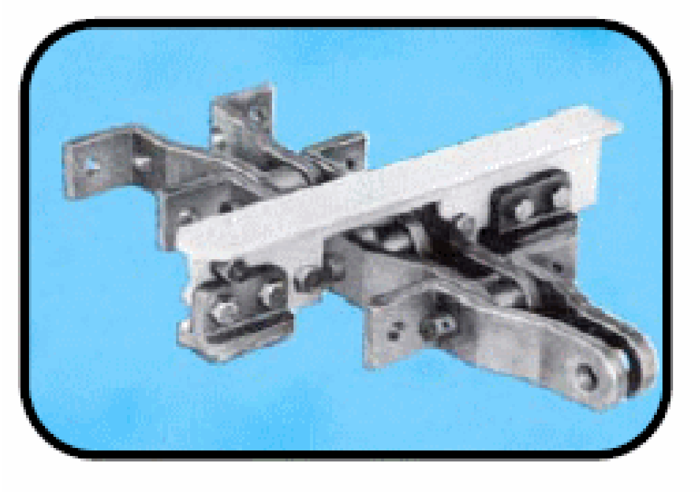


GREEN

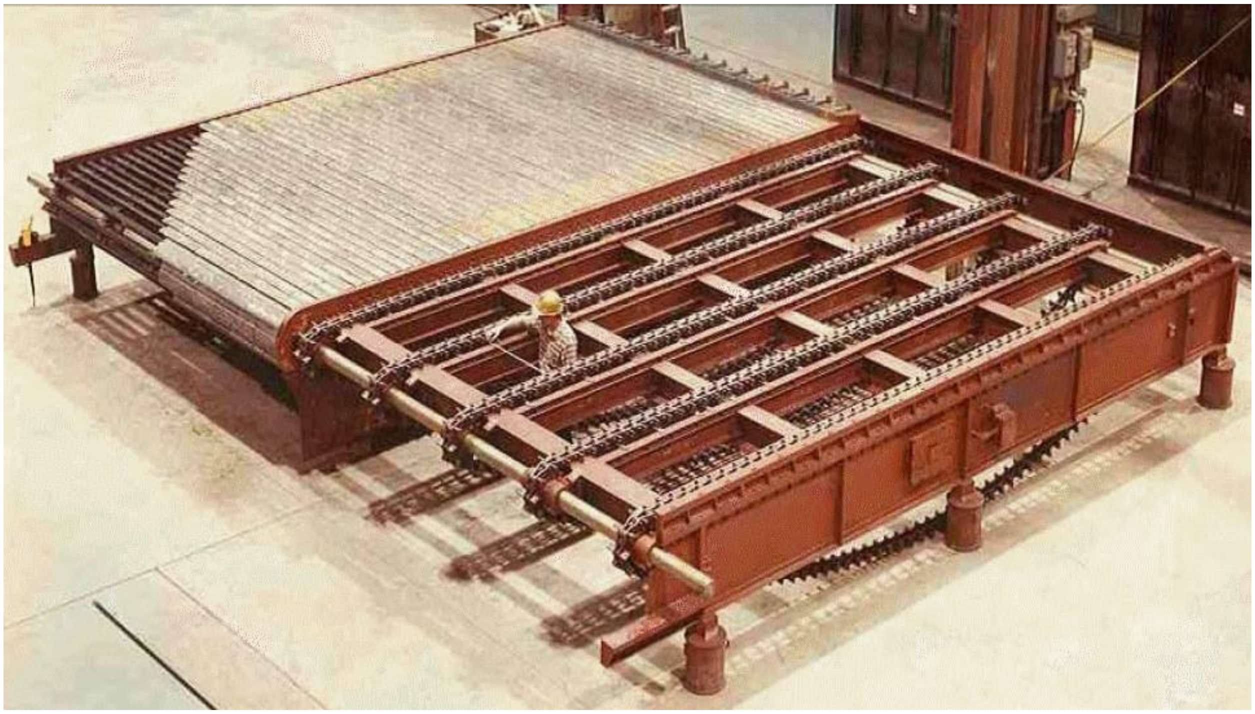
Green Chain Grate Stoker under the boiler with front arch


Side Seal Clip
Heat Resistant GRATE CLIP
Grate Rack
Roller
Top Twin Skid Rail
Drive Chain
Tee-Mount Grate Support for Traveling Grate Stoker

This diagram shows how the grates are attached to the grate rack and how the grate rack is attached to the drive chain on rollers.

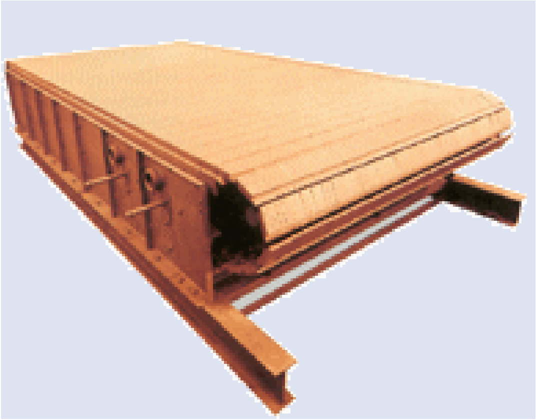


The Tee-Mount grate support to hold the individual grate sections of the traveling grate stoker



The traveling grate stoker at the top left is almost completed and shows how the individual grates are attached to the grate rack. The traveling stoker at the bottom right shows how the chains are attached to the sprocket on the shafts at the ends of the frame and how the chain slack droops at the bottom.

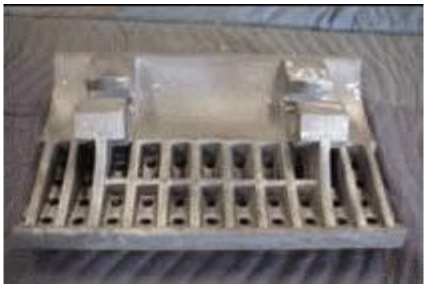
Attaching the top bearing cap on the shaft where the cogs are attached.



Completed traveling Grate Stoker

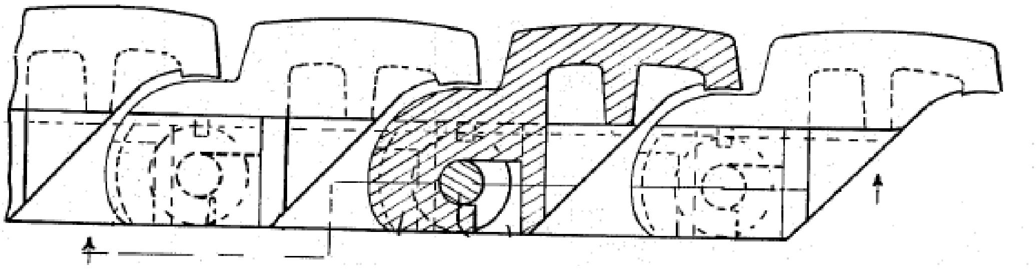
Improved air hole design helps prevent plugging and facilitates cleaning.

Underside of traveling grates showing the attachment clips as they slide over the Tee- mount



Underside of traveling grate showing the attachment clips as they slide over the Tee- mount. Note the holes for air.

Sprockets, chains and grates



Showing how the traveling grate sections overlap to form a flat surface on top of the grate

What properties in coal do you consider when operating a coal stoker plant?

1. Sulfur: Affects clinkering and slagging tendencies; limits economizer exit temperature of flue gas; may cause corrosion of metal in bunkers, etc.; may promote oxidation, heating in storage.

2. Caking and coking: Stoker should agitate fuel bed in proportion to coal's caking tendency. Coals forming weak coke masses are better for fluctuating loads.

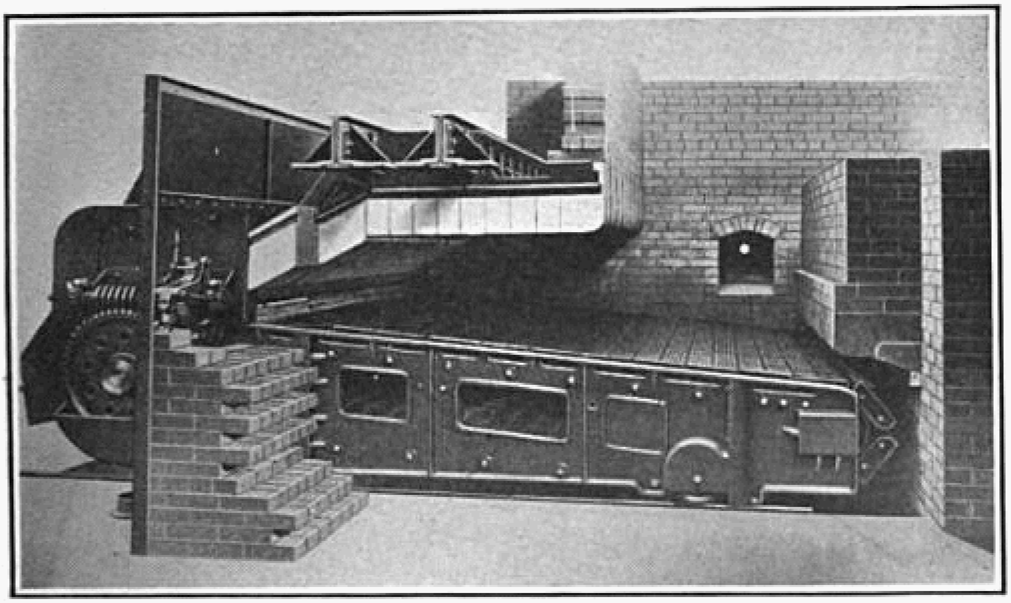
3. Ash content, fusibility temperature: Ash reduces handling and burning capacity; may boost handling cost. Ash content and composition, fusibility temperature in relation to burning rates, fuel bed and furnace temperatures indicate tendencies for clinkering and slagging. Equipment is needed for ash removal.

4. Volatile matter: Affects flame length and thus minimum setting height and furnace volume; influences amount of over fire air needed and how it is applied.

5. Moisture: Reduces fuel handling and burning capacity; may cause handling difficulty (freezing, etc); promotes corrosion in bunkers; must be evaporated in furnace, causing a loss. Surface moisture may prove beneficial to fuel-bed structure (as in tempering).

6. Coal size: Handling equipment should be designed to avoid size segregation. Along with caking qualities, size affects the density and uniformity of the fuel bed. Fuel bed density affects amount of draft needed and air distribution. Excessive fines may lead to high carbon losses and dust problems.

POWER Feb. 1974, W S-3. Stoker plant design keyed to coal analysis



Laclede–Christy Chain Grate Stoker.

Chain grate stoker with ignition arch above the grate on the left. An adjustable gate below the coal hopper determines the fuel depth on the grate. The large holes in the sides of the grate determine the amount of air entering under the top grate surface. Speed of the grate is determined by a steam engine or a variable speed motor. The ash hopper opening is underneath the stoker on the right. Some chain grates have wheels on rails and can be removed from the furnace in case of emergency and for repair.

Best results are obtained on a grate installation of this type when the fuel has a high volatile content and is moderately coking. The limited time allowed for burning dictates a free burning, easily ignited coal, yet the forced draft feature requires somewhat of a caking characteristic to prevent unburned particles from being blown away. This is the reason for the limitation imposed on the underfire air pressure.

Detroit Edison Steam Course, Fuel Burning Equipment, page 60

The fuels most widely used on traveling grate stokers are:

Anthracite, both fresh mined and that dredged from river beds
Semi-Anthracite
Bituminous coal which is non-caking or free-burning
Subbituminous
Lignite
Coke breeze or the finer-sized coke resulting from the manufacture of both metallurgic and domestic coke.

All these fuels can be burned on either the forced-draft chain-grate or the traveling-grate stoker, although one type of stoker is sometimes preferred to the other for use with certain kinds of fuels. The size of coal used for a traveling grate stoker should be 3/4 inch or smaller.

Blue Combustion Engineering page, 6·23

The most satisfactory coals for use on traveling grate stokers have a minimum ash softening temperature of 2100 degrees Fahrenheit, ash content of 6 to 15%, free swelling index of 3 to 5, and a size range of 1 1/4 or 1 inch by 0 with not more than 30% less than 1/4 inch.

Steam Plant Operation by Woodruff and Lammers 4th edition page 150

What kinds of coals are burned on chain grate stokers?

Chain and traveling grate stokers can burn a wide variety of solid fuels, including peat, lignite, bituminous, anthracite, and coke breeze.

Chain grate stokers are used for burning noncaking free-burning high volatile high-ash coals. Coking coal requires agitation and is, therefore, not suited for use on these stokers.

Steam Plant Operation by Woodruff and Lammers 5th edition, page 139.
Steam Plant Operation by Woodruff and Lammers 8th edition page 254

Every type of fuel that is mined, with the exception of caking bituminous coals, can be burned successfully on these machines

Blue Combustion Engineering page 6·1

Is lignite a good fuel to burn on chain-grate stokers?

Yes.

Chain-grate stokers are used for burning non-caking free-burning high volatile high-ash coals.

Steam Plant Operation by Woodruff and Lammers 5th edition page 139

Lignite is a noncaking free burning coal with the highest volatile matter of all coals, its ash content is 9% compared to a range of 5 to 15% for other coals

Stoker Handbook by H.D. Airesman page 19

Lignite has been burned on natural-draft chain-grate stokers with a fair degree of success at rates of combustion up to 30 lb per sq ft of grate per hr. Efforts to burn lignite on forced-draft chain-grate and traveling-grate stokers set in front-arch furnaces, similar to those formerly used with anthracite buckwheat, did not prove very successful. However, instances are on record of rates of burning as high as 75 lb of lignite per sq ft of grate per hour in front-arch furnaces with a 17 inch thick fuel bed.

Blue Combustion Engineering page 6·17

Notwithstanding the high moisture content in lignite, this fuel burns well on traveling-grate stokers. However, the rate of ignition is likely to be slow unless the furnace is properly designed and the fuel is properly sized. Excellent results are obtained by burning lignite in rear-arch furnaces. The maximum sizing for lignite should be 1 1/4-in., with all the fines resulting from crushing left in the fuel. With fuel of such sizing, the fire thickness may be from about 8 to 12 in. The poorer grades of lignite, having moisture contents ranging from about 36 to 40 percent, are somewhat difficult to ignite, and should be prepared with maximum sizing of 3/4-inch to 1-inch. Lignite deposits are rather widely distributed in the western portion of the United States, the principal deposits thus far developed being in Texas and North Dakota. An area of about 60,000 sq miles in the state of Texas is underlaid with lignite. Other states in which this fuel is found are Arkansas, Colorado, Kansas, Montana and New Mexico.

Blue Combustion Engineering page 6·29

Lignite

What is the best stoker to use for coke breeze?

Experience shows that best results are obtained with coke breeze burned on chain-grate and traveling-grate stokers if the maximum sizing does not exceed from 1/2-in. to 5/8., round-hole screen. In some instances, satisfactory operation has been obtained when using breeze having maximum sizings of 3/4-in., and even 1-in., but in such cases careful operation is necessary, even with well designed furnaces.

Blue Combustion Engineering page 6·29

What type of stoker is best for burning Subbituminous coal?

Chain grate and Traveling Grate

The Subbituminous coals vary more in chemical composition than do other ranks of coal, but are all suitable for use on chain-grate and traveling-grate stokers. Because of their usually high content of combustible volatile matter, they ignite easily and burn freely. For that reason, the maximum sizing for use on stokers of this type can be somewhat larger than for other Midwestern bituminous coals.

By adding more air to a chain grate stoker would you get better efficiency from a thick or thin fuel bed?

Complete combustion in the fuel bed cannot be obtained by increasing the supply of air through the fuel bed. Increased air supply increases proportionately the rate of combustion or gasification, but the composition of gas rising from the fuel bed remains the same. This is true as long as the bed is free from holes. When holes are formed, large excess of air may be blown through them into the furnace. For efficient combustion the following conditions are required- a uniform **thin fuel bed**, free from blow holes; an adequate supply of secondary air; and a sufficient furnace volume to enable the gas to burn.

Blue Combustion Engineering page 2·28

What should the ash content be for coals used on chain grate stokers?

The most satisfactory coal for use on chain and traveling grate stokers has an ash content of 6 to 20 percent

Steam Plant Operation by Woodruff and Lammers 8th edition , page 254

For natural draft stokers the ash content should be 5 to 9%.

Steam Plant Operation by Woodruff and Lammers 5th edition, page 136

What is the rate of combustion for forced draft chain grate stokers?

The rate of combustion for a forced draft chain grate stoker is 40 to 50 lb of coal per square foot of grate area per hour.

Steam Plant Operation by Woodruff and Lammers 5th edition, page 139.

Is the use of firing tools on a chain or traveling grate stoker recommended and why?

The use of firing tools on a chain or traveling grate stoker is not necessary. The use of firing tools require opening of the doors to the furnace disturbing the delicate air balance, as great lengths are gone to, to reduce the amount of air that does not go through the grate area. The fact that a chain or traveling grate stoker burns non caking coal removes the need to use firing tools.

Steam Plant Operation by Woodruff and Lammers 5th edition pages 136-137.

What is the combustion rate per square foot of a traveling grate stoker?

The natural draft chain grate stoker shows the lowest operating efficiency over a capacity range which is limited to maximum combustion rate of 40 lb/sq. ft. The preferred operating rate is about 30 lb/sq. ft.

The forced draft traveling grate or chain grate stoker may be used with either a front, combination, or rear arch furnace for burning Midwestern bituminous coals. For front arch installations, the maximum continuous combustion rate is limited to about 50 lb/sq. ft., while for either combination or rear arch designs the rate may be raised to 55 lb/sq. ft.

Blue Combustion Engineering page 6·31

The best operation of these stokers on lignite, over a reasonably wide range, is obtained with the rear arch design. Combustion rates as high as 65 lb/ sq. ft. may be realized without difficulty, because prompt and rapid penetration of ignition is assured, even though the moisture content of the fuel may be as high as 40%.

Blue Combustion Engineering page 6·31

How are combustion rates controlled in a traveling grate stoker?

There are two ways of regulating the rate of coal supplied by a chain grate stoker: the depth of coal on the grates and the rate of travel of the grates. The depth of coal on the grates is maintained between 4 and 6 inches by means of an adjustable gate. The average operating speed of the chain or travelling grate is 3 to 5 in./min.. Variations in rating are obtained by changing either or both these fuel feed adjustments.

Dampers are provided in both natural and forced draft stokers to permit the operator to control the air supply to the various zones. These air supply adjustments enable the operator to control the rate of burning in the various zones and thereby reduce to a minimum the coke carryover into the ashpit. If satisfactory operation can't be achieved by adjusting these dampers, the next step is to adjust the fuel bed depth, or temper the coal,

Steam Plant Operation by Woodruff and Lammers 4th edition page 151
Steam Plant Operation by Woodruff and Lammers 5th edition page 137

How does forced draft combustion air enter the chain grate or traveling grate stoker?

Air enters the furnace through the openings in the grates and through over-fire jets. These over-fire air jets enter the furnace through the front arch or front wall above the arch. The intense heat at the front of the stoker results in distillation of gases from the fuel bed. The combination of over-fire air and the air passing through the fuel bed provides turbulence required for rapid combustion. In some instances, overfire air jets are also located at the rear wall to provide a counterflow of gases in the furnace, promoting increased turbulence and further reducing the emission of smoke.

Steam Plant Operation by Woodruff and Lammers 4th edition page 148
Steam Plant Operation by Woodruff and Lammers. 5th edition page.136.

What is the depth of coal on a chain grate stoker?

The depth of coal on a chain grate stoker is maintained between 4 and 6 inches.

Steam Plant Operation by Woodruff and Lammers. 5th edition page139

What is the average operating speed of a chain or traveling grate stoker?

The average operating speed of a chain or traveling grate stoker is 3 to 5 feet per minute.

Steam Plant Operation by Woodruff and Lammers. 5th edition page139

What should the moisture content be of the coal that burns on a chain grate stoker?

Best results are obtained when the moisture content of the coal is 8 to 10 percent. If extra water is needed, the water should be added 10 to 24 hours before the coal is burned.

Steam Plant Operation by Woodruff and Lammers 5th edition page 140

On a traveling grate stoker, what keeps the grates cool?

The grates are cooled by the ash bed and the air traveling up through the grates from the wind box.

Hollow castings, extending along the frames that hold the traveling grate, are used to reduce the heat from the furnace walls to the side frames.

Blue Combustion Engineering pages 6·8 to 6·9

How is the temperature measured on a traveling grate?

The temperature of the grate material on a traveling grate is measured by the use of a radiation pyrometer. This instrument is placed between the upper and lower grates and is pointed toward the upper traveling portion of the grate (black body). The emission from a radiant body focused upon the hot junction of a small thermocouple in the pyrometer is used. The temperature is proportional to the fourth power of the absolute temperature of the source of radiation. The electromotive force created by this temperature rise is measured by a potentiometer. Radiation emitted when sighted on a black body is measured in degrees Kelvin. Temperature range is 200 - 3500 degrees Fahrenheit but theoretically there is not an upper limit. A thermocouple can be embedded in the upper slide rail on the sides of the furnace that guide the grate.

Kent’s 12th edition pages 18-09 and 18-13

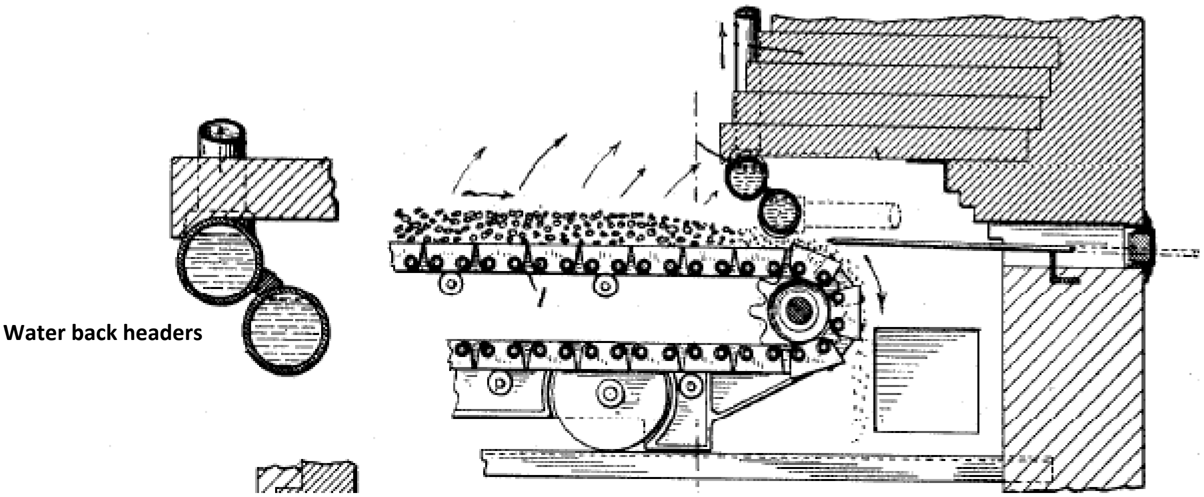
Can two or more traveling grates in the same furnace be varied in speed from one another?

Yes, each grate is connected to a gear box to change the rate of travel, individually from one to another.

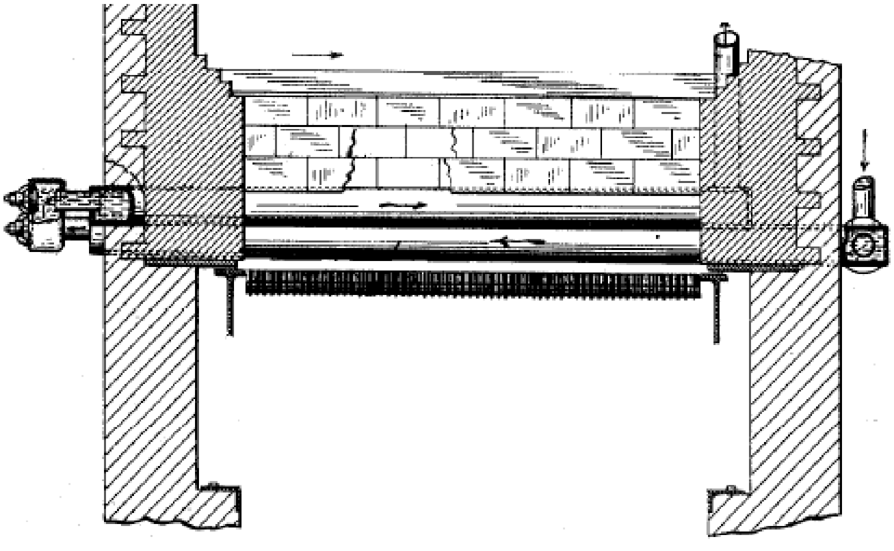
What are "water backs"?

When the clearance between the rear of the furnace and the stoker is reduced to control air leakage, the hot ash comes into contact with the wall and adheres to it, forming clinkers. This condition is prevented by the installation of water cooled tubes, or "water backs," in the rear wall where the refuse is discharged from the stoker. These tubes may be cooled by the flow of low-pressure water supplied for this purpose, or they may be connected to the boiler and form a part of the heating surface.

Steam Plant Operation by Woodruff and Lammers 5th edition page 137



Side view of water backs at the rear of a traveling grate stoker

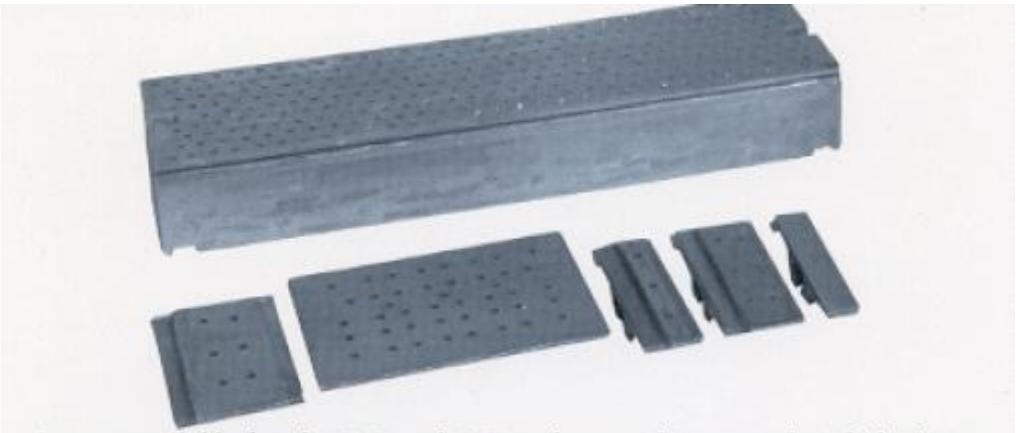


Rear view of the water backs

Name the materials used in the manufacturer of grates.

Grates are made of cast iron.

Blue Combustion Engineering page 6·7

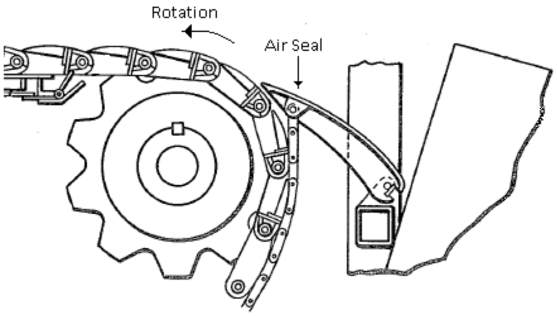


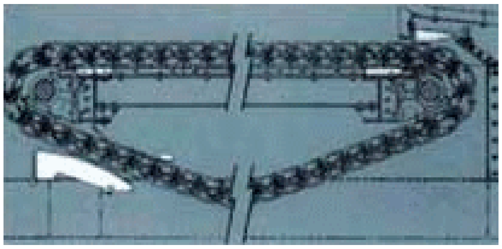
Grates available for the PAD and CAD stokers with improved air hole design. Alloyed gray iron is standard with high silicon/molybdenum ductile iron available for extended service life.

What are air seals used for?

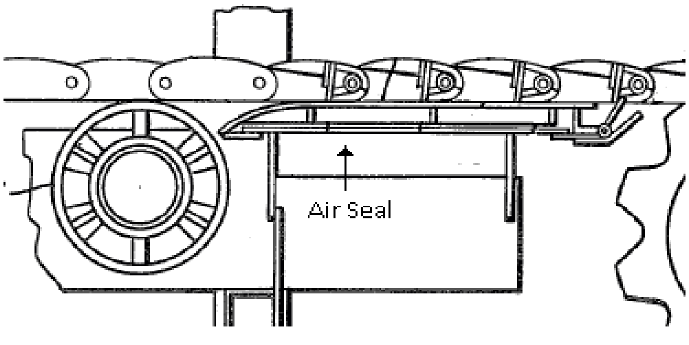
The grates are entirely enclosed by a suitable casing to prevent air infiltration at undesirable points and to promote combustion. Air leakage along the side of the moving grates is reduced by the use of adjustable ledge plates. Where the refuse is discharged to the ash pit leakage is reduced by a damper to seal off the ash pit. The clearance between the traveling grate and the ledge plate should be adjusted to 1/8 inch.

Steam Plant Operation by Woodruff and Lammers 3rd edition page 134





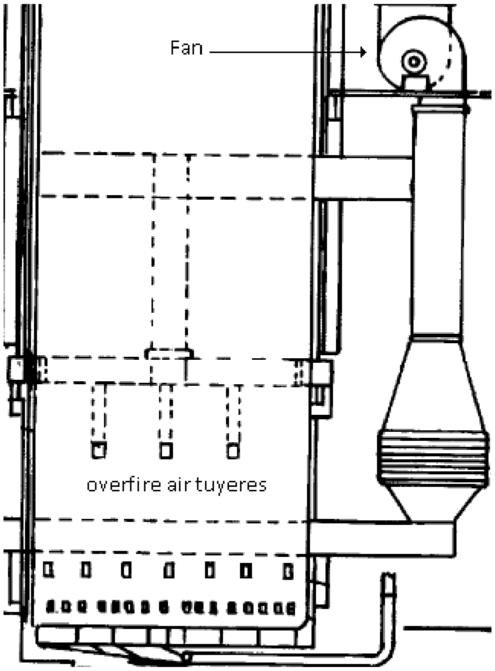
Air seals shown in white on the top and bottom of the grates on the ends

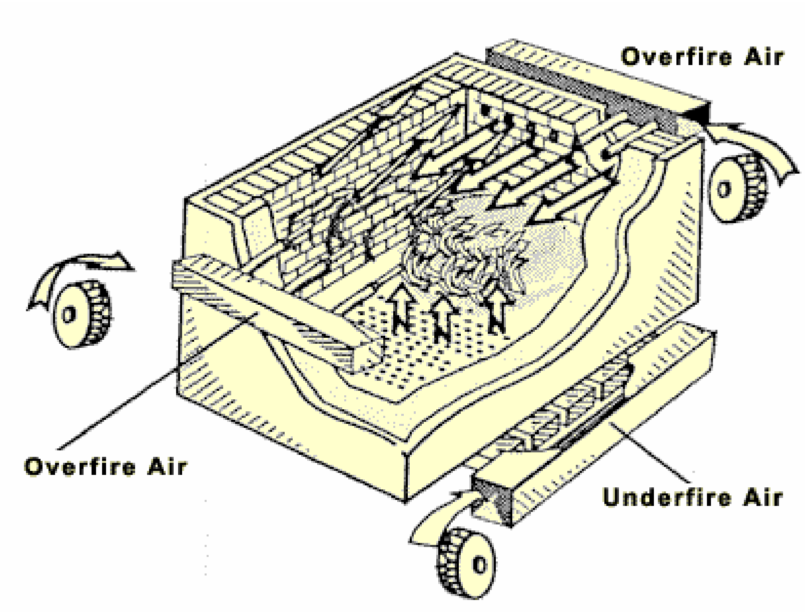


What are rear tuyeres?

Rear tuyeres form the lower back wall of a spreader stoker where the grate meets the rear wall. Their purpose is to promote combustion and help keep the rear section of traveling grate cool where very little ash is available.

Operator Chrysler Sterling Heights Assembly Plant





On a traveling grate stoker, what are the minimum and maximum temperatures for the grates?

There is no preheated air on stokers (no air heaters). The fuel bed on top of stoker is 7% ash on traveling grate and critical temperature of steel is 1100 degrees and combustion of coal is around 850 degrees so the furnace temperature must be between those two temperatures to avoid damage but yet be efficient. Primary air keeps iron work cool.

Joe Grubb

Does a Roney stoker require a forced draft?

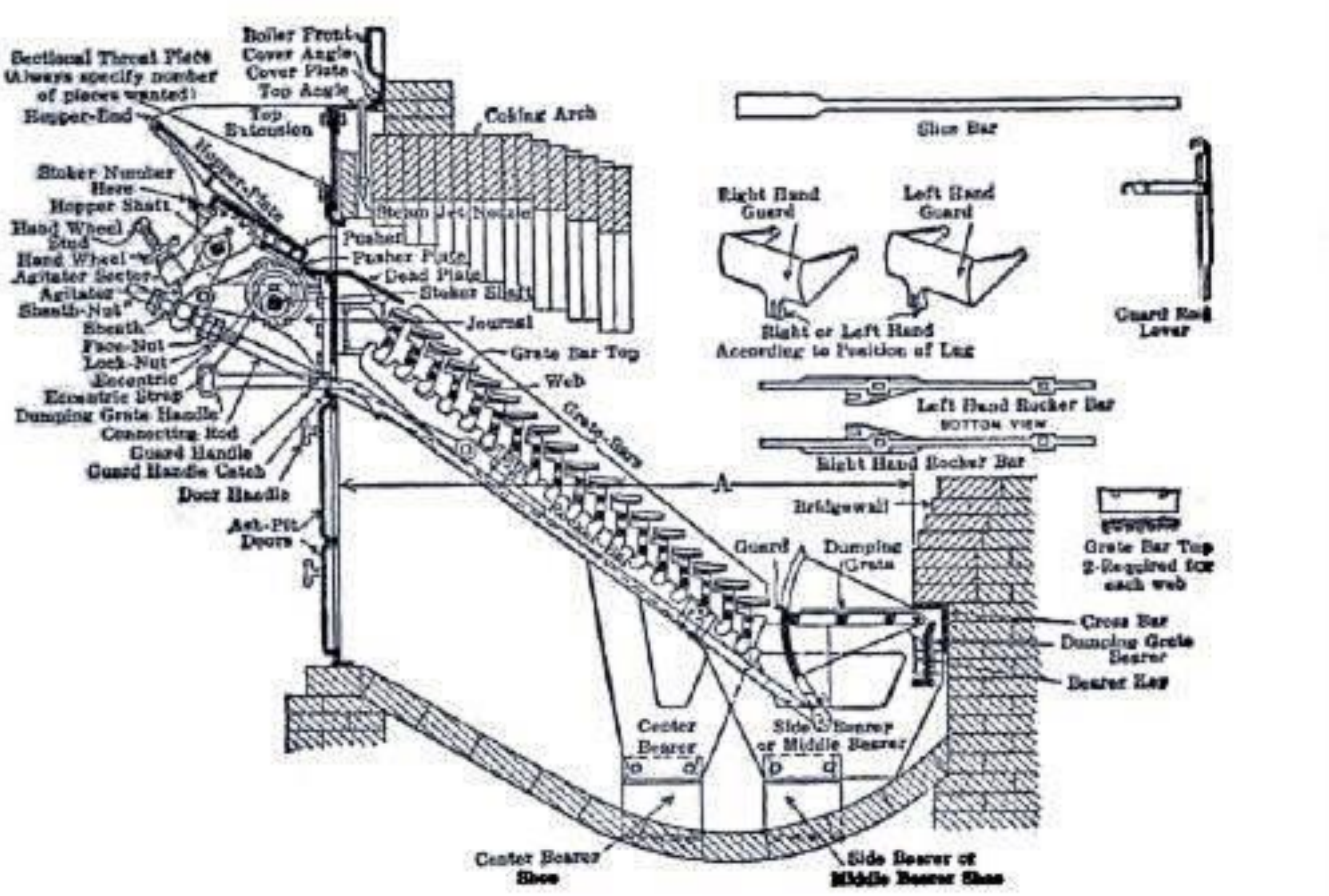
No.

A Roney stoker was an overfeed stoker developed between 1890 and 1900, and at that time the only stokers employing forced-draft were the underfeed and the Coxe traveling grate. Along with the Roney overfeed, some other various types of stokers using natural draft were: Murphy sidefeed overfeed; Green and Playford chain-grates. These stokers are shown on the next pages.

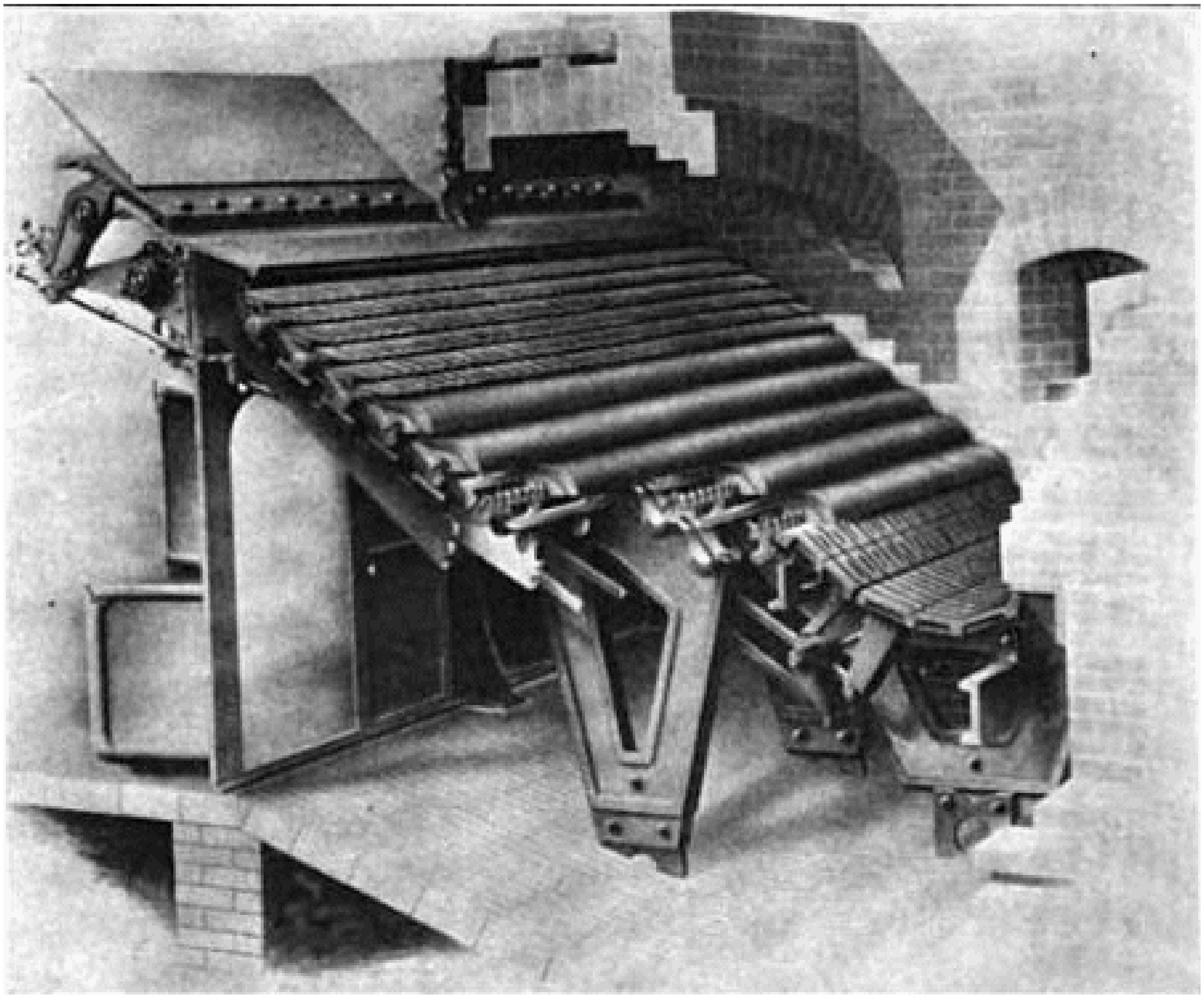
Blue Combustion Engineering page 9·2

The Roney Stoker.—This stoker in the illustration is a good representative of the steeply inclined front feed stoker. It has the grate bars placed across the furnace and each one forms a step just below the one above. The bars are T-shaped in section and are pivoted near their lower ends. The lower ends of the bars rest in slots cut in a rocker bar. This is how they get their rocking motion. The rocker bar is given a reciprocating motion through a rod, which gets its motion from a shaft passing in front of the stoker and is operated by a small steam engine. The coal is fed from a hopper to the dead plate just below the hopper. From there it is pushed onto the grate bars by a pusher plate sliding back and forth over the dead plate. The grate bars oscillate through an angle of about 30°, alternately assuming a horizontal and an inclined position, thus gradually feeding the coal down the incline. The stoker normally operates at about 10 strokes per minute and the rate of feeding the coal is regulated by adjusting a hand wheel which controls the amplitude of the motion of the pusher plate. By the time the coal reaches the bottom of the grates, it is completely burned, and the clinkers and ash may be dumped into the ash pit by means of a dumping grate provided for this purpose.

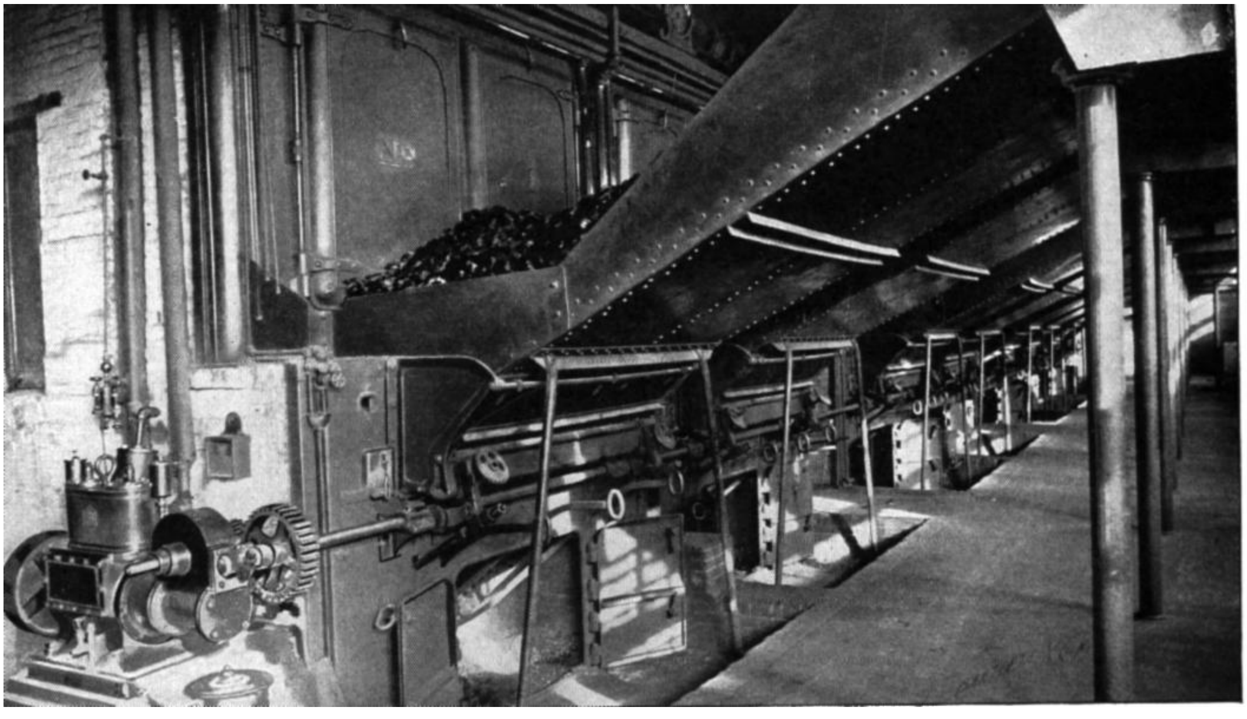
Steam Boilers by Edward Marvin Shealy page 167



Roney stoker.

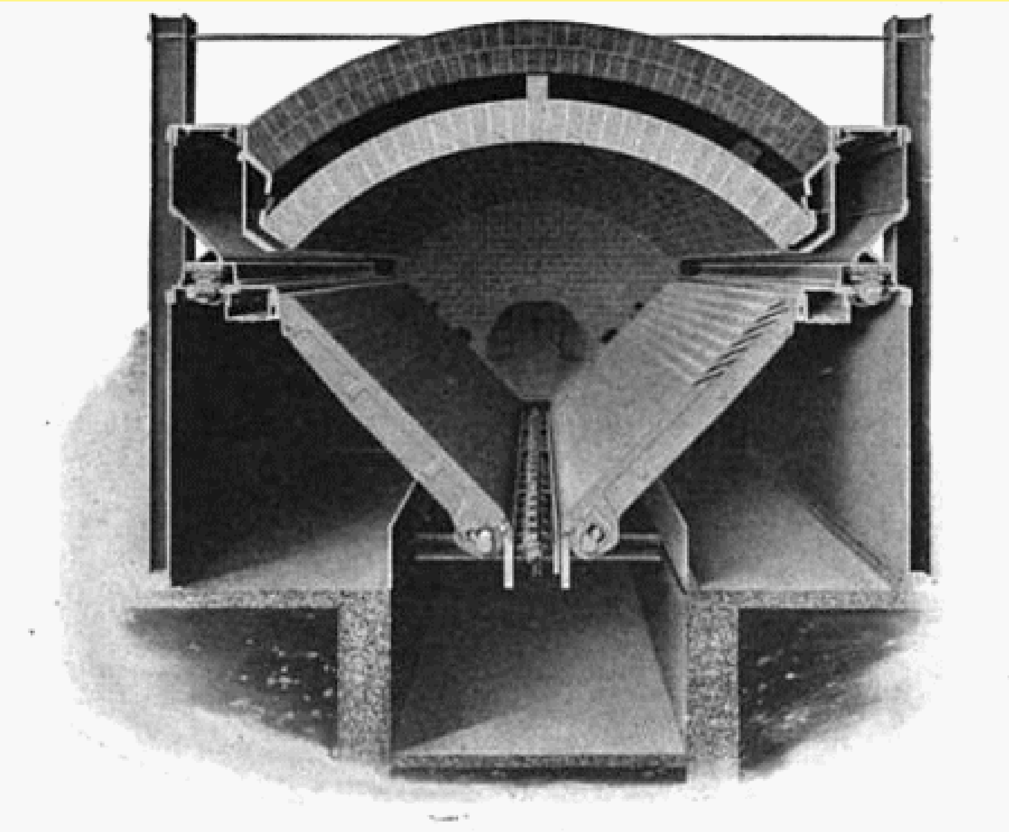


Roney Stoker inside the furnace

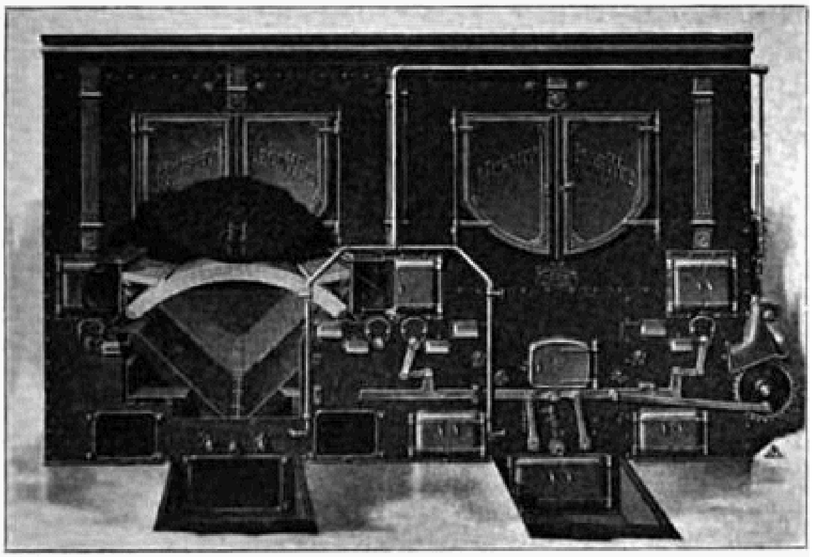


Roney Stoker outside the furnace with a steam engine to control the speed of the grate action. The gearbox attached to the steam engine slows the output speed and increases the torque.

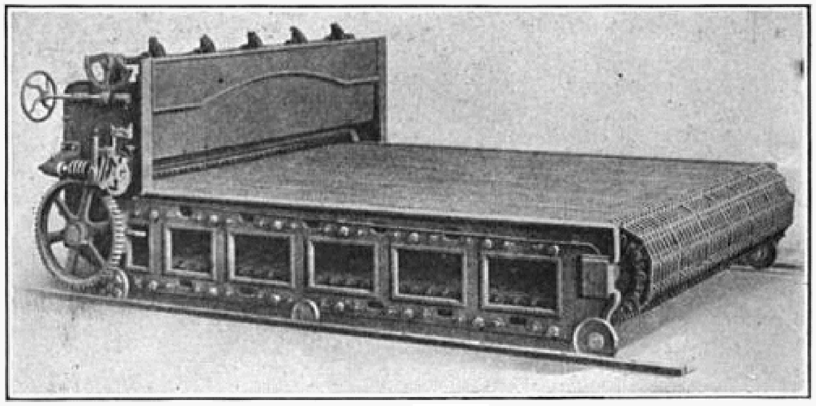
The Murphy Stoker.—The Murphy Stoker represents another style of steeply inclined stoker. This one differs from the Roney stoker in that it has two sets of grates, one placed along each side of and extending the depth of the furnace. This apparatus is, in effect, a Dutch oven with an automatic feeding and stoking device. Coal is fed from hoppers placed along both sides of the furnace. From the hopper, the coal runs onto a coking plate from which it is pushed by a reciprocating stoker box. The grate bars are inclined toward the center of the furnace, and are pivoted near their upper ends. Only the alternate bars are movable, and these are connected to a shaft in the middle of the furnace and at the bottom in such manner as to give them a motion alternately above and below the surface of the stationary grates. This serves to feed the coal down the incline. A hollow shaft with strong teeth on the outside is placed in the bottom of the stoker for clinker and ash grinding.
Steam Boilers by Edward Marvin Shealy page 168



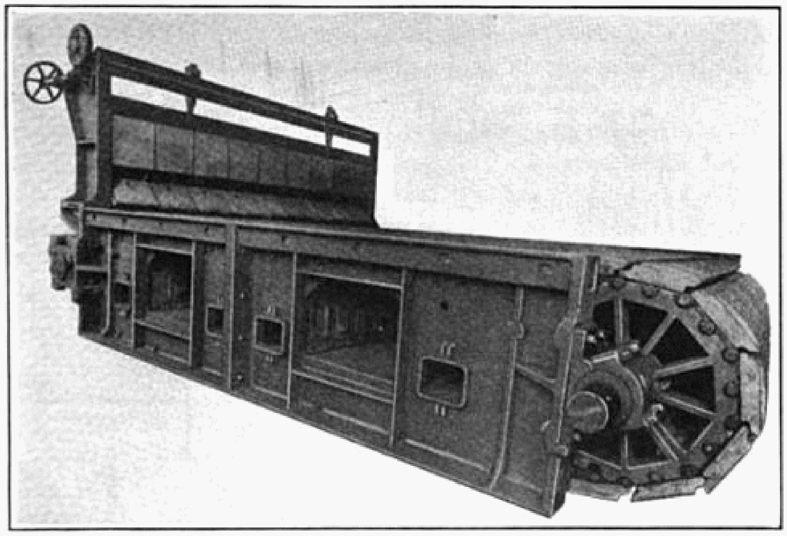
The Murphy Automatic Smokeless Furnace



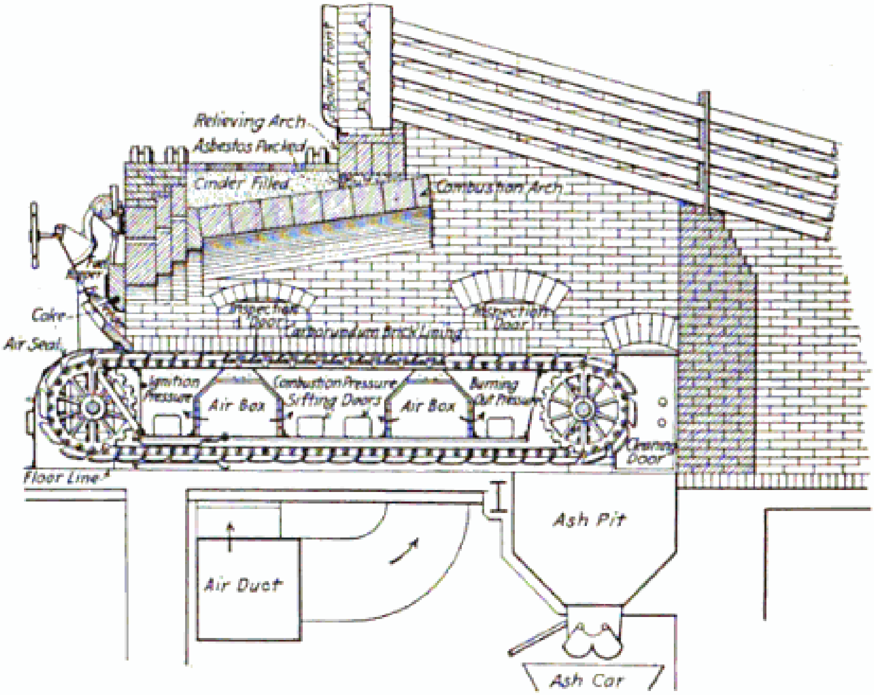
The outside front of the Murphy Furnace with phantom view on the left



Playford stoker



View of Coxe traveling grate for burning coke breeze.



Sectional drawing of Coxe traveling grate.

Coxe Stoker showing forced draft fan ductwork under the stoker with an ignition arch over the incoming coal to ignite it rapidly from the red hot refractory radiating heat on the fresh coal.

Explain the location and purpose of an ignition arch.

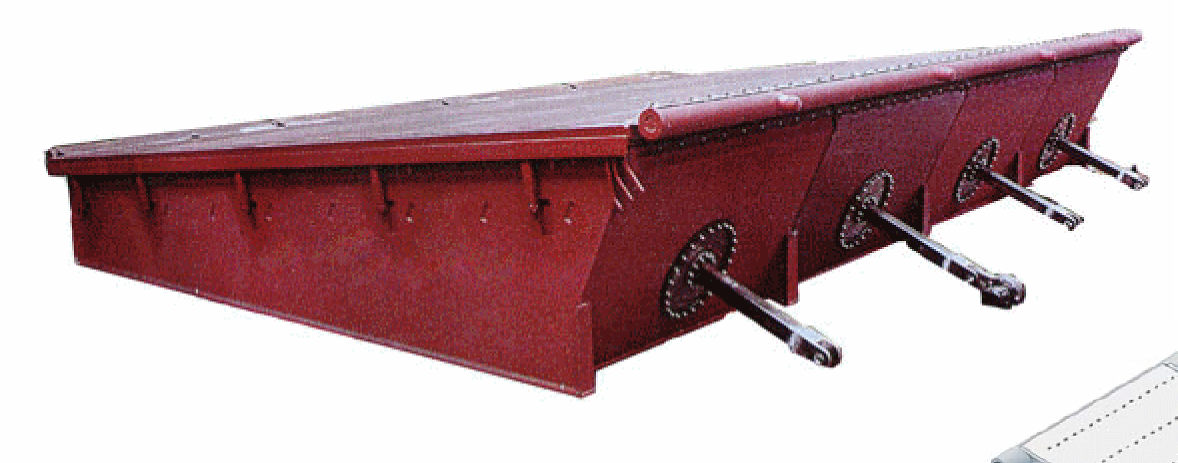
The front arch is the ignition arch, designed to reflect heat to the fuel bed and thus hasten the ignition of the coal. This arch may also house the over-fire air jet nozzle thus also improving intimate and thorough mixing of fuel and air.

Detroit Edison Steam Course - Fuel Burning Equipment

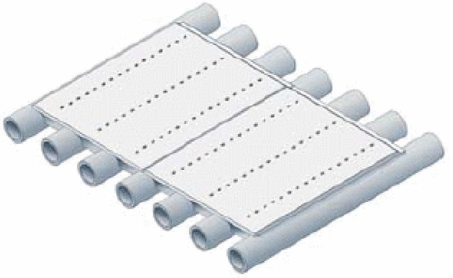
How is the grate of a vibrating grate stoker cooled?

The grates consist of cast-iron blocks attached to water-cooled tubes. These tubes are equally spaced between headers that are connected to the boiler. The connecting tubes between these headers and the boiler circulating system have long bends to provide the flexibility required to permit vibration of the grates.

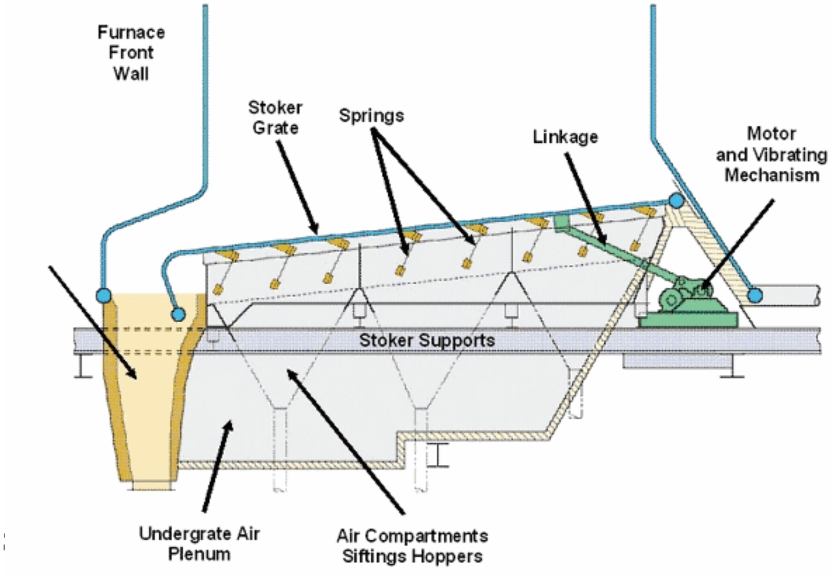
Steam Plant Operation by Woodruff and Lammers 4th edition pages 149-150, 5th edition page138, 8th edition Page 253



The water-cooled vibration grate (HVB) from the side



Water cooling tubes with grate sections on top of the tubes



Water cooled vibrating grate diagram

BITUMINOUS COAL

1. For bituminous coal the gate opening is about 5 inches

2. Coal is run in to cover the first two compartments

3. Kindling is placed over the coal and then is lit

4. Furnace draft is set to .1 inches of water

5. When the kindling has ignited the coal, run the grate at a speed slow enough to hold ignition at the gate, thus gradually lengthening the fuel bed

6. Air is admitted under additional compartments as required

7. Stoker may have to be stopped and started to maintain ignition

ANTHRACITE COAL

1. The gate opening is about 3 1/2 inches

2. Coal or coke breeze is run in to cover the grate back to and including the first full compartment under the nose of the reverse arch

3. Kindling placed over the fuel is then lit and air is admitted under the compartments covered by the fuel bed

4. A dead plate usually covers the first compartment, preventing admission of air to the fuel bed at this point

5. The furnace draft is regulated and the coal is slowly fed in on the grate to maintain ignition

NORMAL OPERATION

1. For bituminous coal a 5 to 7 inch fuel bed is common

2. For anthracite coal a 3 1/2 inch to 5 inch fuel bed is common

3. Speed of the grate is adjusted so that ignition is maintained at the forward end of the stoker

4. The fire should not be allowed to burn back to the coal gate nor burn past the first compartment

5. Changes in load are handled by varying forced draft fan damper and stoker speed

6. Speed of the traveling grate is from 3 to 5 inches per minute

7. Forced draft chain and traveling grate stokers can burn 40 to 50 pounds of coal per square foot of grate surface per hour

BANKING A CHAIN OR TRAVELING GRATE STOKER

1. When burning bituminous coal, the gate is raised to an 8 to 10 inch opening and the coal is run in for a length of about 4 feet. With Anthracite or coke breeze it is not customary to raise the gate above its normal position, but fresh fuel is run in, as in the case of bituminous coal

2. The forced draft fan is stopped, and compartment side doors are opened to permit air to be drawn through the chain grate to prevent its overheating and to supply the small amount of combustion air need for the banked fire. Furnace draft is regulated by adjusting the induced draft fan control or the boiler uptake damper. Incidentally, this procedure should be followed whenever the forced draft fan is shut down

3. The induced draft fan is stopped, or the boiler outlet damper is closed to a point just sufficient to carry off the gasses from the banked fire and maintain a slight draft within the furnace

4. During a banked fire period, fresh fuel is run in from time to time as the banked bed slowly burns, taking care that the fire does not burn back under the gate where it might damage the gate structure. As a precaution, when burning bituminous coal, it is well to run most of the coal out of the stoker hopper, retaining only enough to provide a coal seal at the gate. This will prevent an inrush of cold air under the gate and also damage to the gate.

5. When starting up from bank with bituminous coal, the gate is lowered to the normal position. Forced and induced drafts are set for operating conditions. With anthracite or coke breeze, the live bed is run back to the stoker compartment where heavy blasting is normally applied to toss burning particles forward to aid ignition.

EMERGENCY SHUTDOWN

1. Increase chain or travelling grate speed to maximum.

2. Raise gate to maximum opening to feed maximum amount of green coal

3. Shut off the air supply and run the burning fuel into the ashpit

A traveling grate 8 feet wide by 16 feet long has coal 6 inches deep, traveling at 6 inches per minute. Coal weighs 56 pounds per cubic foot. The grate is loaded with burning coal at the start. How much coal will burn in one hour?

6 inches per minute = .5 feet per minute

.5 feet per minute X 60 minutes in one hour = 30 feet

30 feet traveled + 16 feet of coal on the grate at the start = 46 feet traveled total

8 feet wide X 46 feet of travel = 368 square feet of total grate covered with coal

6 inches is .5 feet

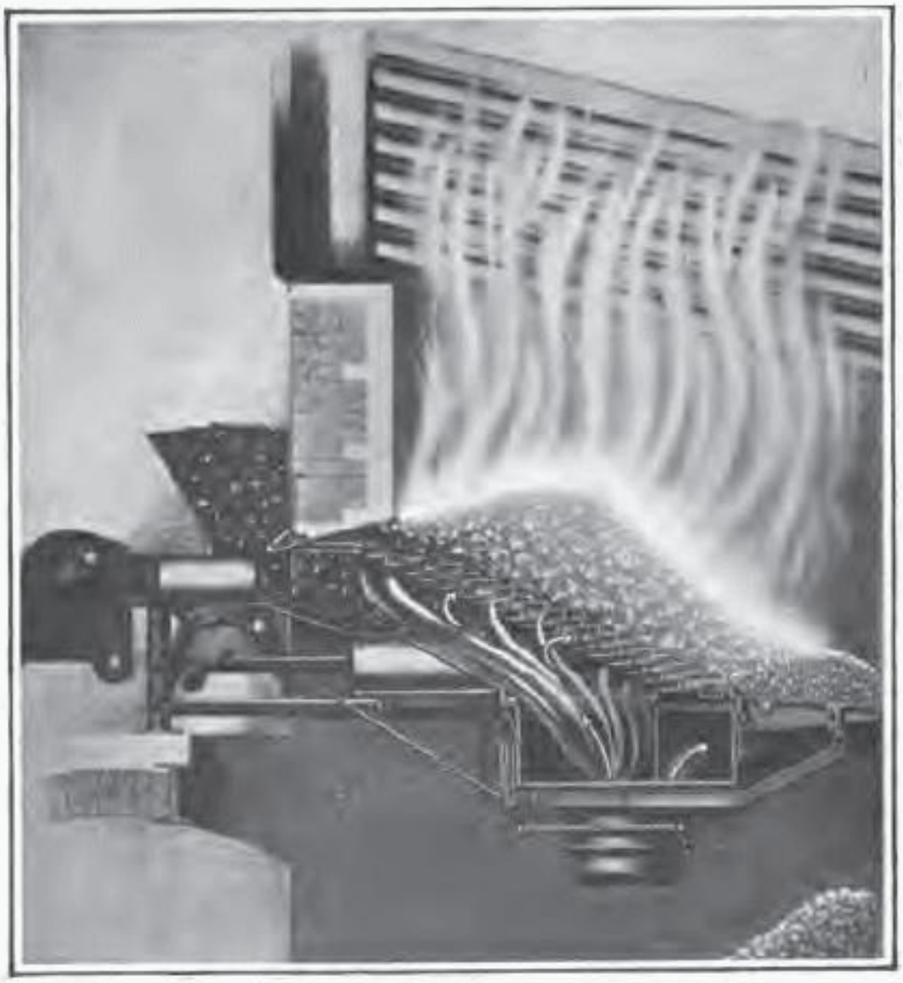
.5 feet high X 368 square feet = 184 cubic feet
56 pounds per cubic foot x 184 cubic feet =10,304 pounds of coal burned total

Chapter 7 Underfeed Stokers

What is the advantage of the thicker fuel bed being carried on an underfeed stoker as compared to a chain grate stoker?

It is advisable to carry a thick fuel bed on the stoker to protect the grates and tuyeres from the furnace heat and to prevent the formation of holes through which air can pass without coming in contact with the fuel. Moreover large amounts of fuel on the grates are an advantage when there is an increase in the demand for steam.

Steam Plant Operation by Woodruff and Lammers 5th edition page 143



Early Form of the Taylor Underfeed Stoker.

What is the rate of combustion on an underfeed stoker?

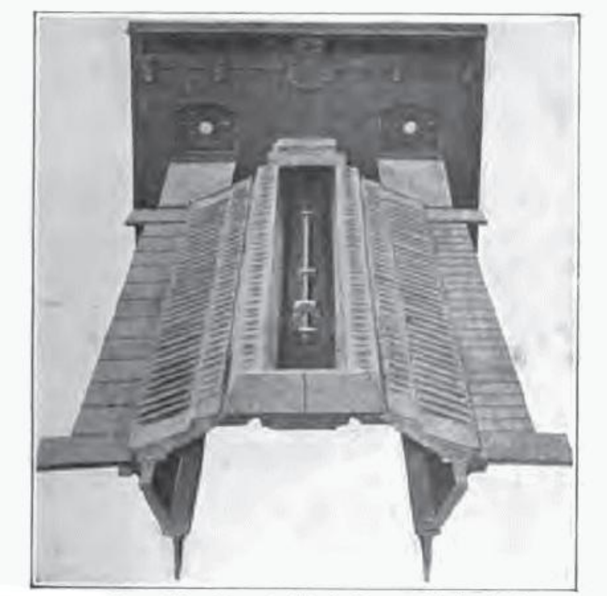
When the fusing temperature of the ash exceeds 2500 degrees Fahrenheit, combustion rates in excess of 60 lb of coal per square foot of stoker area may be successfully maintained.

Steam Plant Operation by Woodruff and Lammers 5th edition page 146

What is the purpose of the secondary ram on an underfeed stoker?

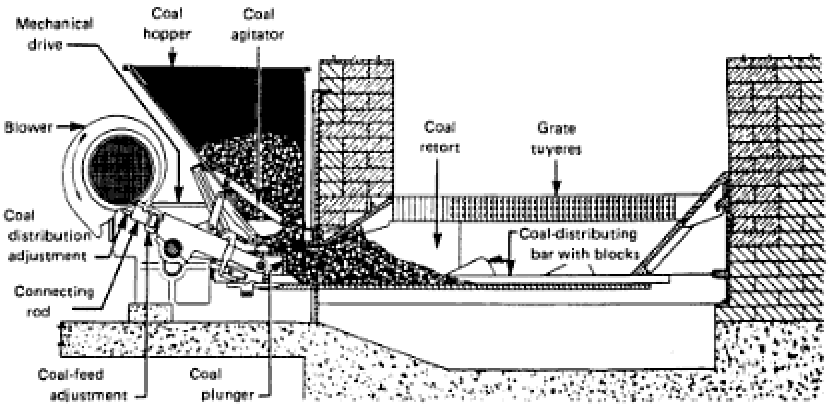
The secondary ram driving arm is adjustable so the movement can be varied to obtain optimum fuel bed conditions.

Steam Plant Operation by Woodruff and Lammers 5th edition page 142



Rear View Detroit Single Retort Underfeed Stoker

This is a good picture that shows the secondary ram shoes in the bottom of the retort attached to a rod. By adjusting the speed of the secondary ram pushers in relation to the main ram, you can adjust the contour of the fuel bed. The retort is the trough in the center of the picture. The tuyeres are on the top and sides of the retort. The dumping grates are on both sides of this single retort underfeed stoker.



This side view shows the main ram on the left pushing coal into the retort. The secondary ram pushers are in the retort. The wedge shaped pushers move the coal down the trough and out of the retort over the grate tuyeres.

Why should low-fusion-ash coal be avoided on an underfeed stoker?

Low-fusion-ash coal is to be avoided because of its tendency to form clinkers. The tuyeres depend upon a covering of ash to protect them from the furnace heat, and low-ash coal may not provide adequate protection, resulting in outages and excessive maintenance.

Steam Plant Operation by Woodruff and Lammers 5th edition page 143

What is the windbox pressure under the fuel bed of an underfeed stoker?

The windbox pressure varies from 1 to 7 inches of water, depending upon the stoker design, fuel, and rating.

Steam Plant Operation by Woodruff and Lammers 5th edition page 147

Why should you not allow the coal hopper run empty while an underfeed stoker is operating?

Never allow the coal hopper to run empty or the supply chute to clog while the stoker is in operation, since this will cause the coal to burn in the retort and the tuyeres to become overheated.

Steam Plant Operation by Woodruff and Lammers 5th edition page 148

At a location 3 feet from the front wall, what should the fuel bed depth of an underfeed stoker be?

The fuel bed depth 3 feet from the front wall should be 16 to 24 inches. The correct depth depends upon a number of factors, including the coking tendency of the coal and the amount of coarse and fine particles that it contains.

Steam Plant Operation by Woodruff and Lammers 5th edition page 148

When should the coal in an underfeed stoker start to burn?

The coal in an underfeed stoker should start to burn when the coal reaches the tuyeres, because the coal burning in the retort will cause the tuyeres to overheat. When the coal is first introduced into the retort, it is heated and begins to give up its volatile gasses. Insufficient air to the tuyeres section or too great a travel of the secondary rams will cause the fuel to pass over the tuyeres before it is burned. One must operate somewhere between these two conditions.

Steam Plant Operation by Woodruff and Lammers 5th edition pages 148-151

How much coal can be burned on the grate of a multi-retort stoker per square foot?

Combustion rates on the stoker grate may be limited by a number of factors, or a combination of factors, such as cinder emission, slow ignition and penetration, excessive furnace temperatures and clinker adhesions to walls, and drifting of fuel to the rear of the stoker. More often, however, the formation of troublesome clinkers, difficult to dispose of, is the limiting factor. The latter affects the distribution of air to the grate surface, and causes excessive ashpit losses and high maintenance. However, satisfactory operation is obtainable with combustion rates of about 40 lb/sq ft/hr. for a continuous rating and a peak rating less than 60 lb for continuous discharge and clinker grinder stokers and with approximately 85% of these values for dump grates. For the high ash, low fusion ash coals and the drifting coals, lower combustion rates are desirable, probably around 35 lb/sq. ft./hr. for continuous rating.

Blue Combustion Engineering, page 4·15

Where does the primary air come in on a multiple retort stoker?

The air is admitted to the tuyeres through dampers hinged at the lower side of the tuyere support. These dampers are in different sections from front to rear. The number of sections will depend on the length of the retort. Each section is operated separately by controls located at the stoker front to obtain the desired air pressure under each zone.

Blue Combustion Engineering., pages 4·5, 4-6

Where in the fuel bed does the combustion of carbon take place in an underfeed stoker?

In the oxidation zone, above the tuyeres.

To fully understand fuel bed burning, it must be understood that four distinct zones exist in the fuel bed. These four zones are known as the:

1. distillation zone
2. reduction zone
3. oxidation zone
4. ash

In the distillation zone, the green coal receives heat from the furnace and the volatile matter is distilled off so as to form the coke in the reduction zone. In the reduction zone, the carbon dioxide moves through the reduction zone where it passes over the hot coke. This excess of carbon reduces the carbon dioxide to carbon monoxide which, in turn, passes upward through the distillation zone to be burned above the fuel bed to carbon dioxide. In the oxidation zone, the coke is burned to carbon dioxide with the air rising up through the grates. Between 40% and 60% of the heat is released above the fuel bed, and the success with which burning is accomplished at this point determines the efficiency of the operation. Unless all of the solid carbon particles are burned completely, soot and smoke will result, and unless the carbon monoxide is burned to carbon dioxide, heat is lost.

Detroit Edison Steam Course Fuels and Combustion page 23

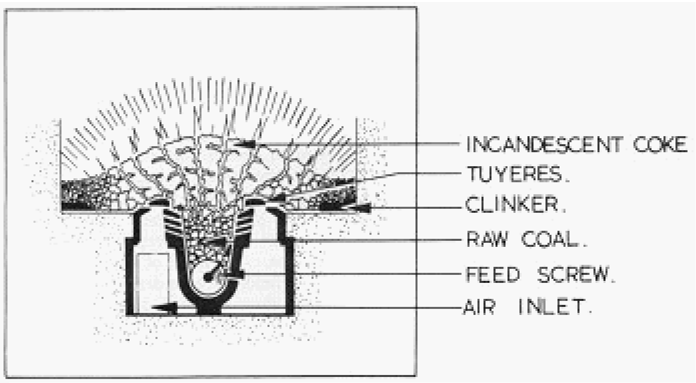
What type and size of coal should a horizontal underfeed stoker use?

The following characteristics are given as a general guide to the selection of coal. They should be supplemented by plant checks and experience to determine the most satisfactory selections, considering both the ease of operation and the cost. Coals for use on single retort stokers should have a minimum ash softening temperature of 2,350º Fahrenheit, ash content of 5 to 7%, free swelling index of 4 to 6, and a size range of 1 1/4 inch or 2 inch by 0 with not more than 30% less than 1/4 inch. Multiple retort stokers use coals having the same ash softening temperature with an ash content between 7 and 8%, free swelling index of 5 to 7, and top size of 2 inches with the same minimum size limitation of not more than 30% less than 1/4 inch. As the free swelling index increases, the top size should be increased and the amount of fines decreased. Coarse coal tends to segregate in the coal-conveying equipment, causing uneven feeding and burning

Steam Plant Operation by Woodruff and Lammers 4th edition page 160

What is the purpose of the windbox?

The windbox serves as a means of providing and directing air to the fuel for combustion. It serves as a means of inspecting the tuyeres of an underfeed stoker.

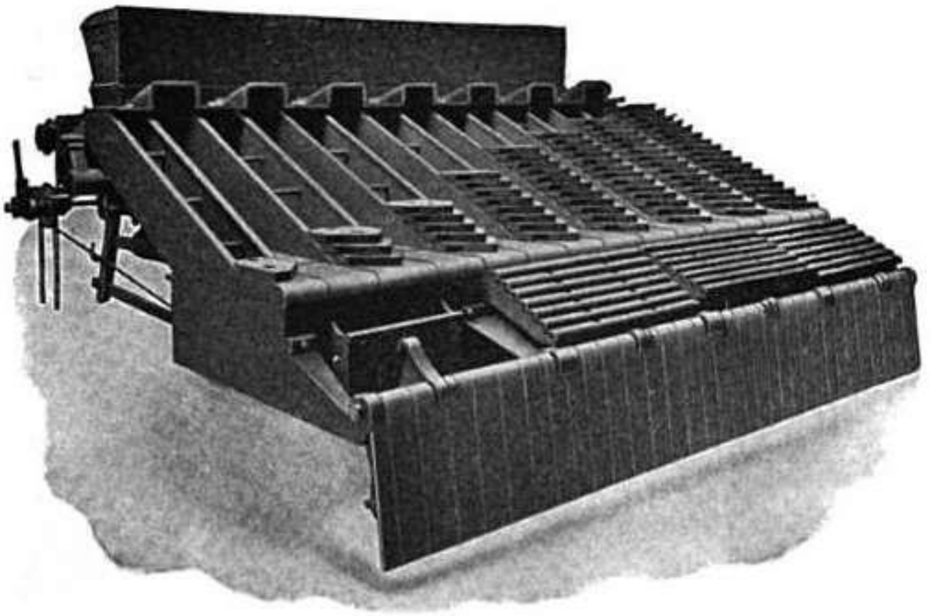


Windboxes are on either side at the air inlet on the diagram

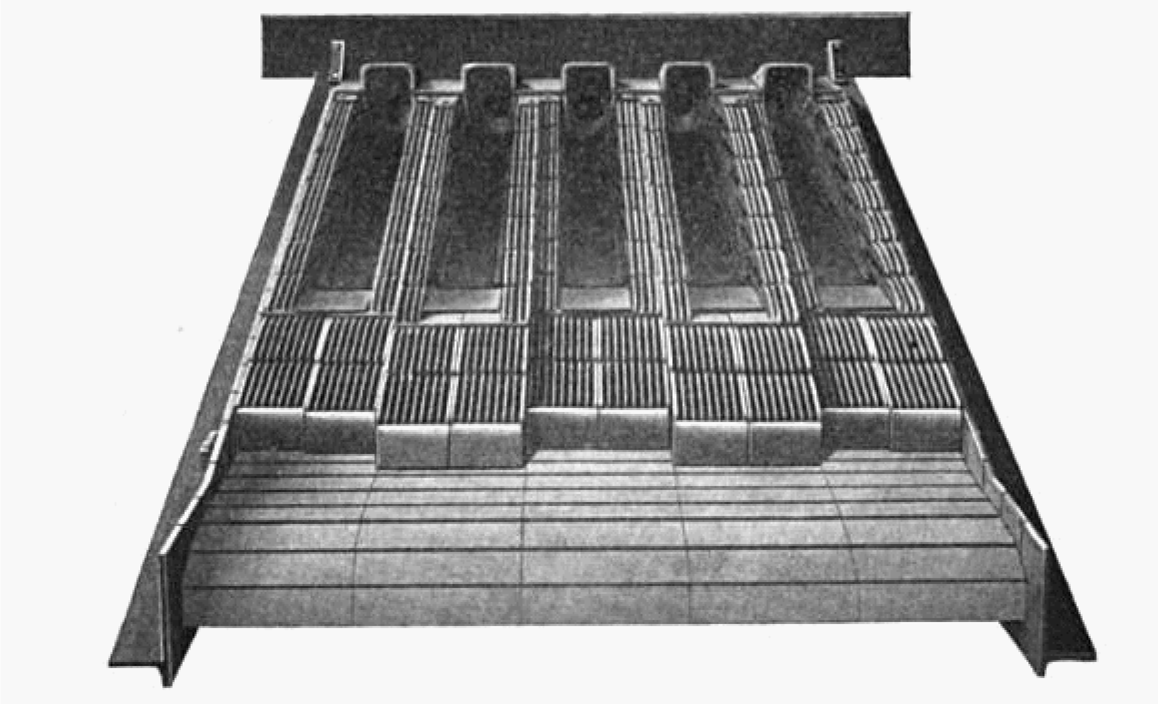
What type and size of coal should a Taylor stoker use?

The Taylor underfeed stoker was the pioneer stoker of the gravity underfeed type and it is used extensively in large central stations. It differs from the Riley stoker mainly in that the sides of the retorts remain stationary; a feeding ram and one or two distributing rams are located in each retort; the dump plates do not reciprocate but are dumped by either hand or power, and the rams are driven by a special form of connecting rod which has an attachment to each ram. All grades of free burning bituminous coals can be used. The fuel bed varies from 2 to 3 feet in depth.

Elementary Steam Engineering by Edgar MacNaughton page 174



THE TAYLOR GRAVITY UNDERFEED STOKER.

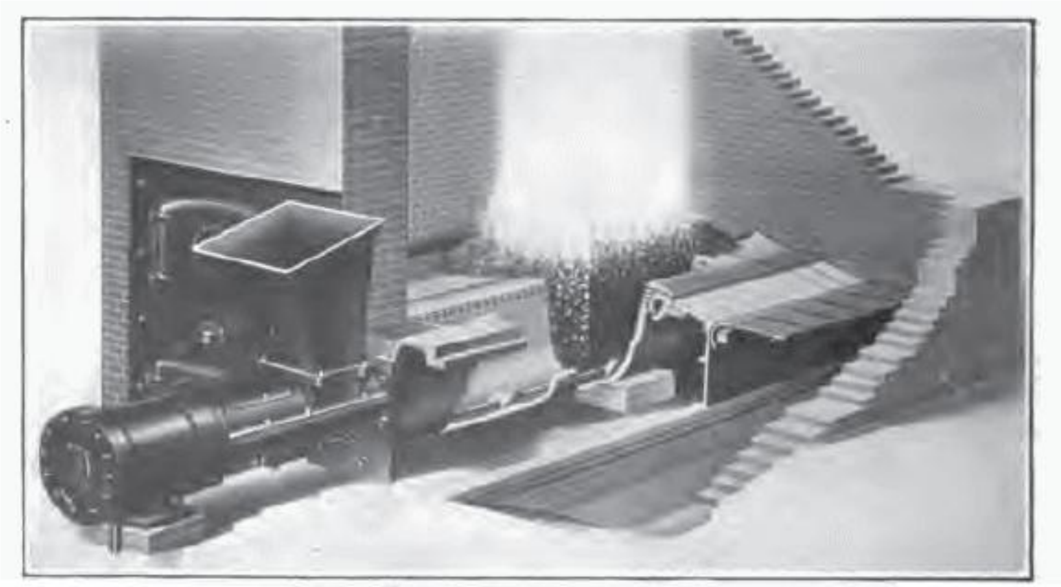


THE RILEY STOKER.

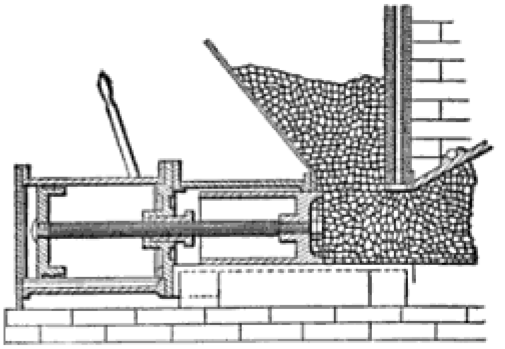
What type of stoker is a Jones stoker?

The Jones Stoker is the underfeed type. This stoker is very simple in construction and has few moving parts. It consists of a retort, which is placed inside the furnace, and a feeding mechanism placed outside. The retort is trough-shaped and along each side at the upper edge is placed the tuyeres for admitting air under the bed of coal. The feeding mechanism consists of two cylinders fitted with pistons placed one in front of the other. The two pistons are placed on a single piston rod, and therefore move together. The outer or actuating piston is acted upon by live steam from the boiler and as this piston moves in, it pushes the other piston or ram which in turn pushes some coal from the hopper into the retort. As the ram forces more coal into the hopper, some of that which was already there is forced upward toward the top and in this way the bed of coals assume the form of a ridge extending down the middle of the furnace; being thicker in the center and thin along the edges. In order to prevent the coal from heaping up too much in the front of the furnace, a couple of pusher blocks connected to the piston rod are placed in the bottom of the retort, which by their movement to and fro, serve to somewhat level the fire. A fan is used to supply air under the stoker through a duct. From under the furnace, air passes through the tuyeres on each side of the retort and on up through the burning coal. The steam engine driven fan and the feeder ram speed can be controlled automatically by boiler steam pressure. Ash is removed from cleaning doors at each side of the boiler underneath the dumping grates.

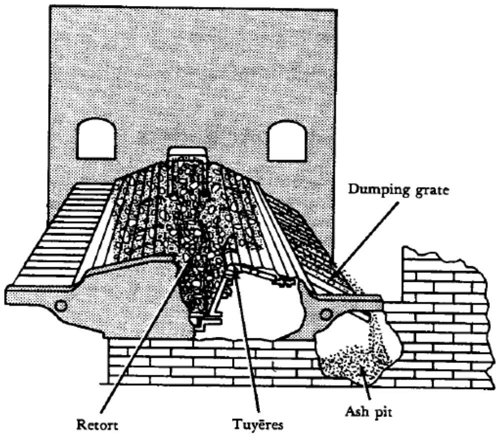
Steam Boilers by Shealy page 170 - 172



Jones Single Retort Side-dump Underfeed Stoker



Jones Stoker Side View



Single-retort underfeed stoker

On an underfeed stoker, what is the dead plate next to the dump grate covered with?

Mainly ashes with a small amount of burning fuel.

Very little time is available to consume any residual carbon after the refuse leaves the extension-grate section of the stoker.

Blue Combustion Engineering page 4‧21,

The ashes collect on the dead plate and are removed through doors located at each side of the retort. When larger capacity is desired, more than one retort is placed in the furnace, with a dead plate between each pair of retorts.

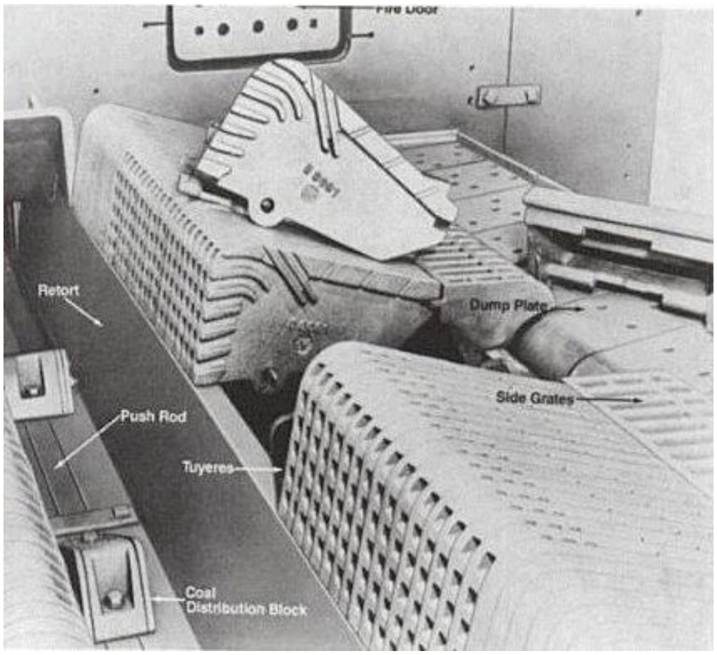
Elementary Steam Engineering by Edgar MacNaughton page 170

On an underfeed stoker, where the dump grates and moving grates come together, what should this area be covered with?

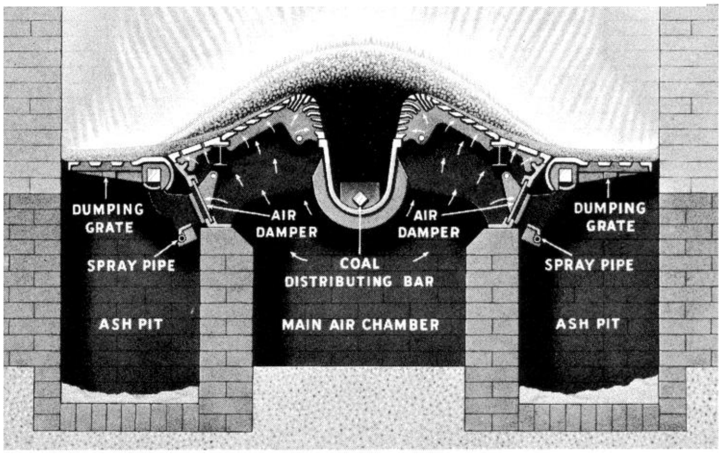
Ash and coke.

As the coal burns slowly it moves from the retort towards the sides of the furnace over the grates. As the fuel moves down the grates, the flame becomes shorter since the volatile gases have been consumed and only coke remains. A portion of the coke finds its way to the dump grates, and a damper is provided to admit air under the grates in order to further complete combustion before the ashes are dumped.

Steam Plant Operation by Woodruff and Lammers 8th edition page 244



The drawing below is a sectional view of the stoker on the left. In this drawing you can see how the coal is pushed out of the retort and the round shape it forms as it spreads over the tuyere toward the ashpit. By adjusting the air dampers, you can completely burn the coal before it lands on the dumping grate. The spray pipe will wet the ashes before removal.

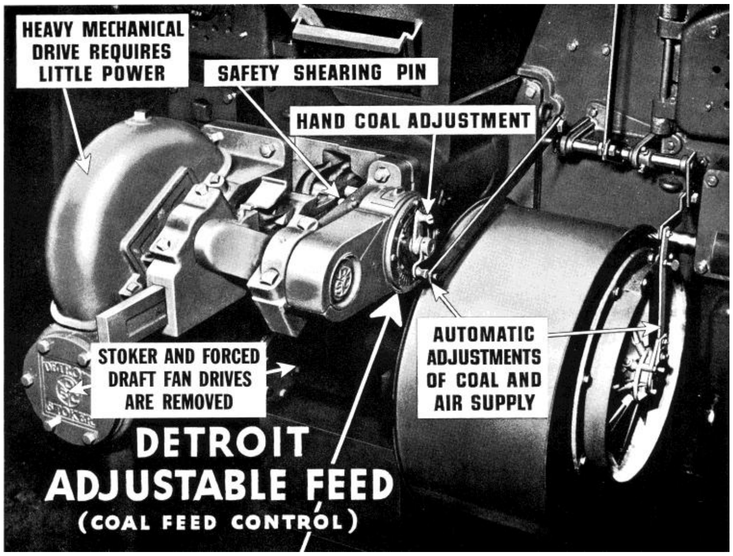


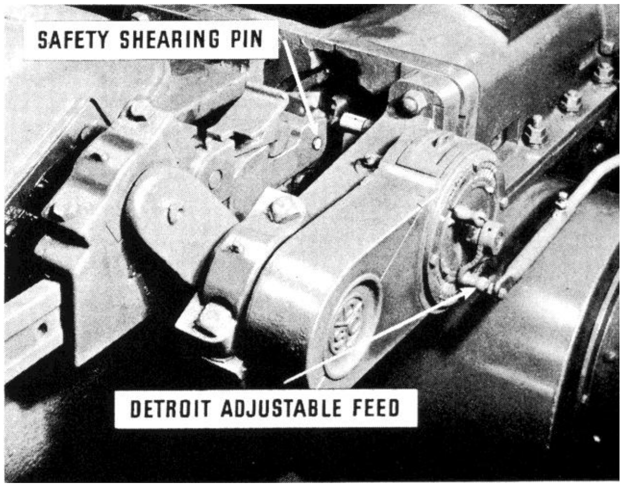
The picture above shows that the tuyeres are made of cast iron plates with ribs that create square air holes called tuyeres when they are assembled together. The side grate or dead plate has coal and ash on it in normal operation. The retort has no air holes and no combustion should take place in the retort. The coal distribution blocks on the secondary push rod moves the coal to the end of the retort and push the coal out of the retort and over the tuyeres. Combustion should begin as soon as the coal is in contact with the tuyeres.

If you break a shear pin on a stoker and you do not have the correct shear pin, what should you do?

An obstruction in the coal tube, feeder, or traveling grate may result in breaking of a shear key or operation of a similar protective device. The obstruction should be removed and the machine free to turn over by hand before the motor is restarted. No attempt at power operation of the unit to free the obstruction should be made. Broken portion if the shear key or other pieces of metal in place of a standard shear key should not be used if considerable damage to stoker parts is to be avoided.

ASME Section VII Care of Power Boilers. Section C6.401(a).


HEAVY MECHANICAL DRIVE REQUIRES LITTLE POWER
SAFETY SHEARING PIN
HAND COAL ADJUSTMENT
STOKER AND FORCED DRAFT FAN DRIVES ARE REMOVED
AUTOMATIC ADJUSTMENTS OF COAL AND AIR SUPPLY
DETROIT ADJUSTABLE FEED
(COAL FEED CONTROL)



What is the heat release of a single retort underfeed stoker?

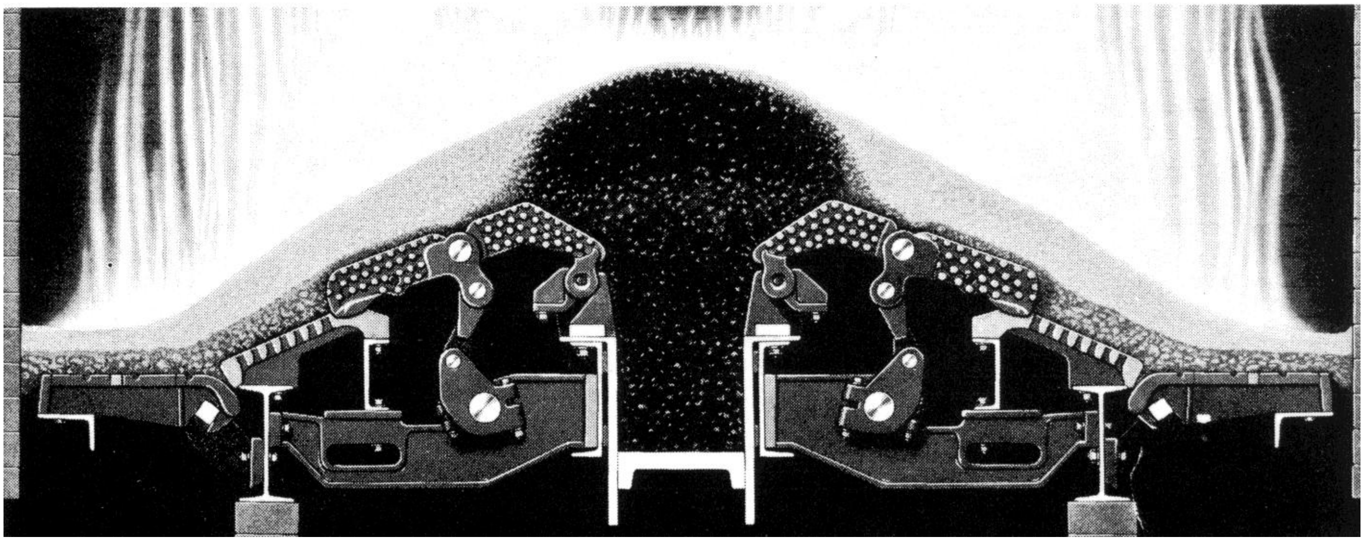
With the smaller sizes of stokers, the combustion rates are preferably limited to around 20 lb per sq ft per hr continuously, with two hour peak, ratings of 25 lb. The preferable combustion rates on the larger stokers are around 30 lb per sq ft per hr continuously, with two hour peaks up to 40 lb.

Blue Combustion Engineering page 3·15

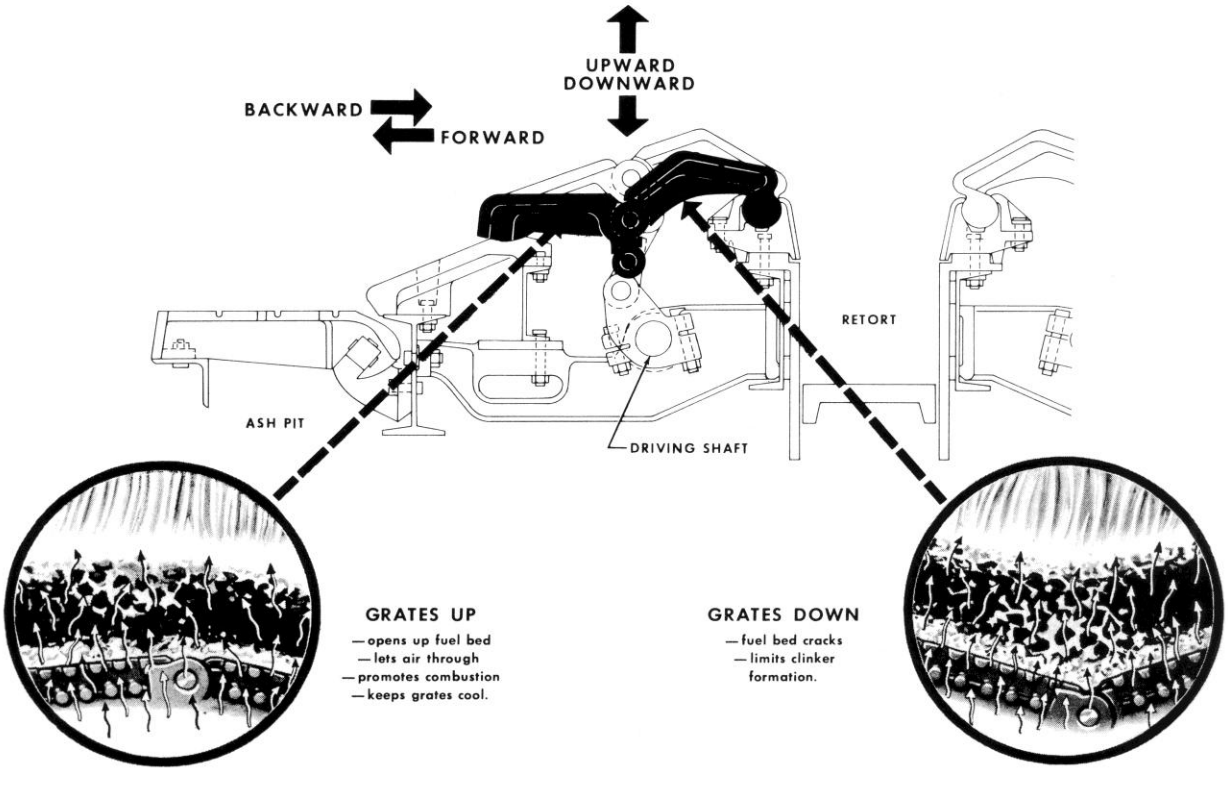
Regarding a chain grate stoker, a hand fired stoker, or a single retort underfeed stoker, which can burn the most coal per square foot of grate surface?

Underfeed single retort stokers burn the most by burning 90 to 100 lbs. per square foot of grate surface with zoned-air control. Without zoned-air control, best operation is at combustion rates of 35 to 45 lbs. per square foot of grate surface. Chain-grate stokers with natural-draft combustion rates range from 20 to 30 lbs. per square foot of grate surface per hour, with a maximum of 60 lbs. when burning bituminous coal. With anthracite or coke breeze, combustion rates range from 30 to 38 lbs. per square foot of grate per hour with forced draft of 1.5 to 2 in. of water, with maximum and minimum rates of 55 and 10 lbs. respectively. Hand fired stoker combustion rates average from 15 lbs. per square foot of grate surface per hour of anthracite with natural draft, to 35 lbs. per square foot of grate surface per hour of lignite, semi bituminous, and some bituminous coals.

Kent's 12th edition p. 7-64, 7-66, 7-68, 7-69



Single retort underfeed stoker with an undulating grate that moves up and down and left and right to break up any masses of coking and clinkering coal.



This picture shows the undulating action of the single retort Detroit Stoker

STARTING A SINGLE RETORT UNDERFEED STOKER

1. Start the motor and feed in sufficient coal to cover the tuyeres to a depth of about six inches
2. Stop the motor and open the boiler and fan dampers
3. Build a wood fire on top of the coal by laying oily rags on top of the wood and igniting with a match
4. Close the fire doors
5. When the coal is burning freely, restart the motor and adjust the blast gate for about 1/4 opening, carrying only a very low air pressure under the fuel bed and feed in the coal slowly.
6. After the coal is thoroughly ignited, slowly increase the coal feed and air supply to gradually heat up the boiler and setting.
7. Adjust the air supply by adjusting the blast gate and the coal feed by sliding the adjusting block forward or backward on the connecting rod.
8. Maintain draft in the furnace between .005 to .1 inches of water above the fuel and between 1 to 7 inches of water below the fuel

NORMAL OPERATION

1. Build up the fuel bed to between 10 to 12 inches above the tuyeres. A coking coal will require a deeper fuel bed than a noncaking coal.
2. Set the blast gate to maintain the desired boiler pressure
3. Set the coal feed by adjusting the ram stroke to maintain a constant level in the fuel bed.

ASH HANDLING

1. Keep ashpit and fuel bed clean
2. Carry a fuel bed of 6 inches over the dumping grate section
3. About 30 minutes before dumping, the auxiliary air supply dampers should be opened to burn up the combustible on the dumping grates
4. Rake to even the coal depth on the dump grates and fill any holes
5. Dump only the ashes above the dumping grates. The ashes on the side grates should remain in the furnace and be used to protect the side grates from the heat
6. When cleaning, close the blast gate to prevent flame from blowing out the fire door
7. Use the slice bar to remove clinker from the side walls and bridge wall
8. Do not let ashes accumulate in the ashpit. Remove them immediately

ECONOMICAL OPERATION

1. Carry a low draft in the furnace by adjusting boiler damper
2. Keep fuel bed free of air holes in the bed
3. Do not carry a hot fire over the dumping section
4. Do not stop the coal feed with air pressure in the stoker air chamber. This allows fire to get down into the retort and burn out parts of the stoker.
5. Inspect the air chamber daily and remove any siftings that may have accumulated there
6. Siftings should be dropping directly below the retort from the groove for the push rod. If siftings stop, the groove is plugging up with carbon or tarry residue and should be taken down at the first opportunity to be cleaned with kerosene

BANKING THE FIRE

1. Burn the fire down

2. Close the blast gate and boiler damper and feed in a large amount of fresh coal so that all of the stoker iron will be protected from the heat with fresh coal. Shut off the fan but do not completely close the damper

3. Never bank the fire by shoveling coal in through the fire door

4. If the fire is to be banked for a period of time, fuel should be fed in about twice a day.

5. In stopping the stoker after banking the fire, care should be taken to stop the ram in the "in" position. This will seal off the hopper and prevent the fire from working back into it

6. In starting up from a banked fire, keep the blast gate closed and feed in sufficient coal before opening up the forced draft air supply so that there is no possibility of fire in the retort

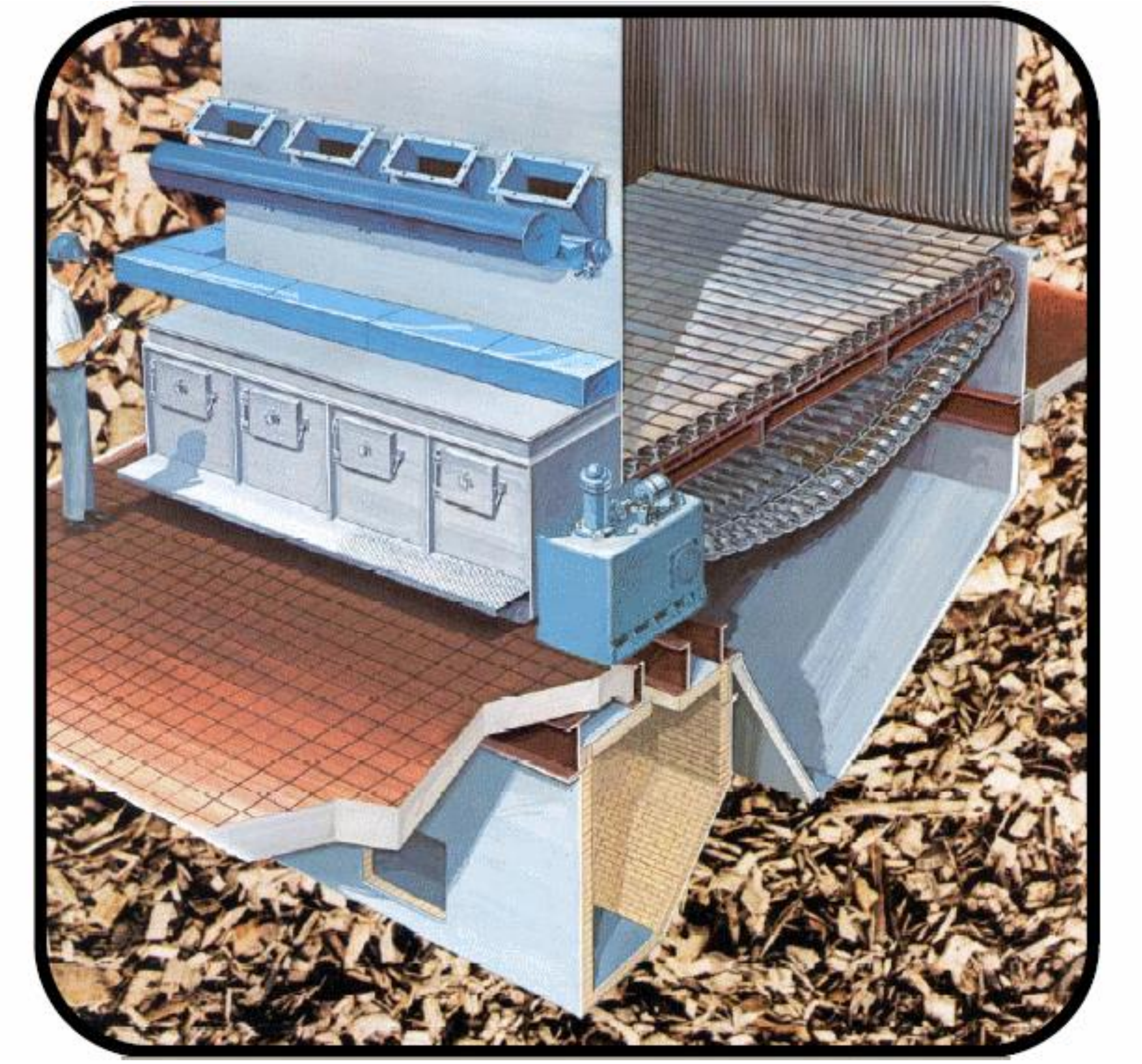
MAINTENANCE

1. Daily
    a. Check oil levels in upper and lower chambers of the worm gear drive
    b. Grease wrist pin, connecting rod crank end bearing, crankshaft bearings shear pin assemblies, and large worm shaft bearings
    c. Oil the chain with machine oil
2. As needed - Fill motor bearing grease cups and screw them in while making sure grease is not getting on motor windings
3. Once a month - Examine and replace any damaged castings
4. Every three or four months - Clean silent chain with kerosene and soak in light machine oil
5. At the end of the heating season - Drain, clean, and refill the upper and lower chambers of the drive with fresh oil

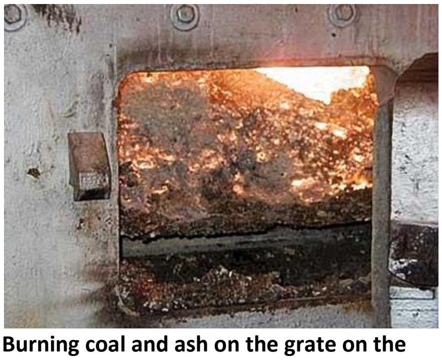
PROBLEMS IN OPERATION

1. Too thin a fire will overheat the iron-work
2. Do not allow the stoker to operate with an empty hopper
3. Do not allow flame to blow through the dumping grates. This will burn the grates. Open the auxiliary air dampers to the ash pit part way to get the flame above the bed of coal.
4. Stopping the coal feed with air pressure in the air chamber will burn the tuyeres
5. Do not operate the stoker with pressure in the furnace. Keep the boiler damper closed as far as possible to provide only a slight draft in the furnace
6. If the shear pin breaks, clear the obstruction and remove the coal above the ram before replacing the shear pin and putting the stoker back into operation. Lift the chain guard to replace the shear pin
7. The fuel bed may be kept level from front to rear by the adjustment of the stroke of the push rod. If the fuel bed is light in the rear a longer block should be used. If the fuel bed is light in the front and heavy in the rear, a shorter block should be used. This adjustment is made when the stoker is first placed into operation and should not have to be changed except for a different fuel.

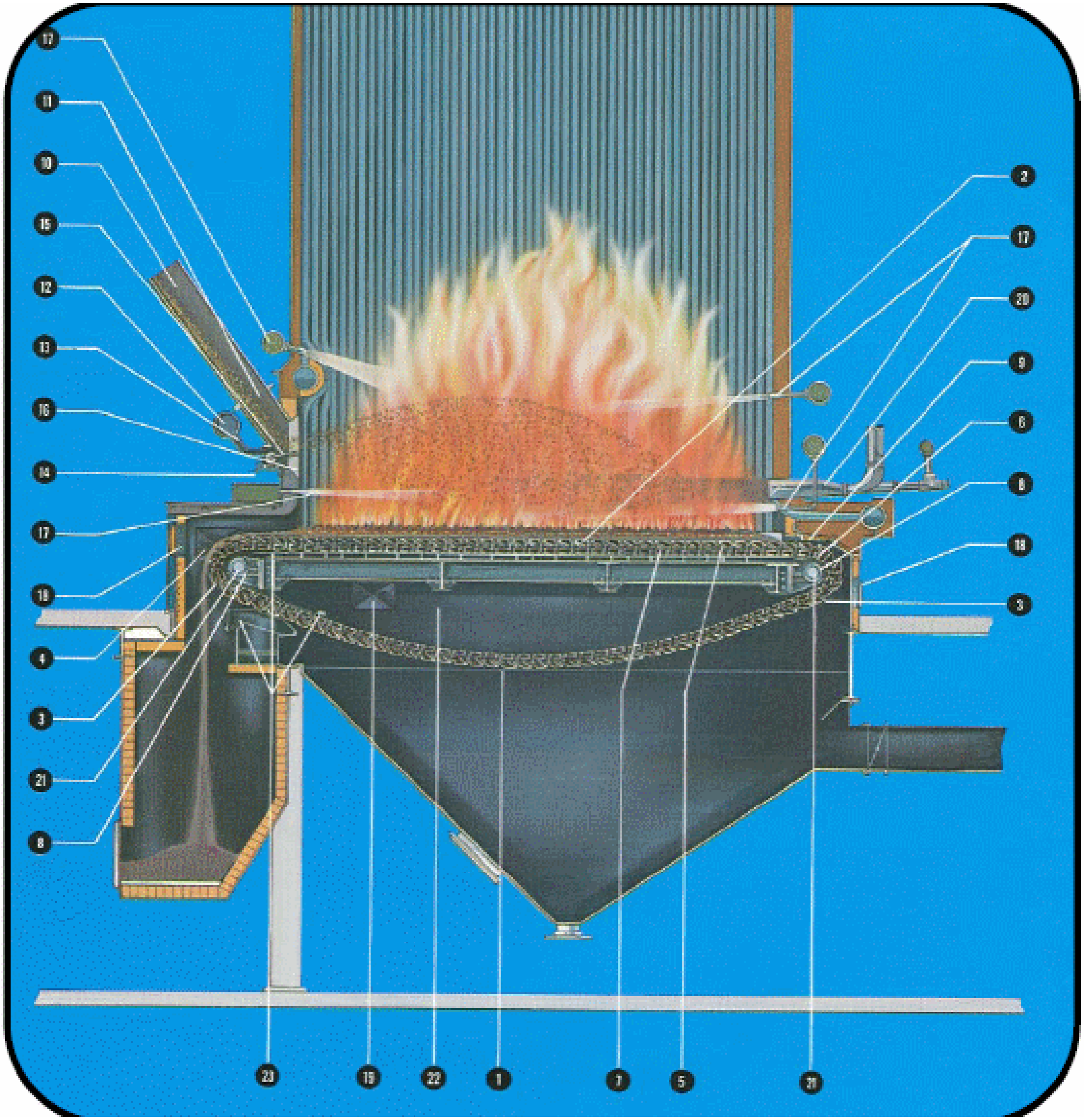
Chapter 8 Spreader Stokers



Keystone Spreader Stoker showing the traveling grate moving toward the operator. The steel ash hopper underneath the grate also allows forced draft air to enter under the grate. The Blue square duct in the front is connected to the overfire air, which can be from the forced draft fan or a separate overfire air fan. The 4 darker blue boxes on the front are where the spreaders will be connected. The hydraulic box on the right hand side controls the speed of the grate. The 4 doors in the front allow the operator to see the condition of the fuel bed, although he must be careful of flarebacks. The rear tubes at the back of the furnace cool the ash and help prevent clinkers from forming there. The firebrick lined ashpit at the front collects the "bottom ash" and a vacuum system will send it to a hopper outside.



Burning coal and ash on the grate on the spreader stoker at Moores Park in Lansing



Cross Section Through The KEYSTONE ENERGY Travagrate® Stoker

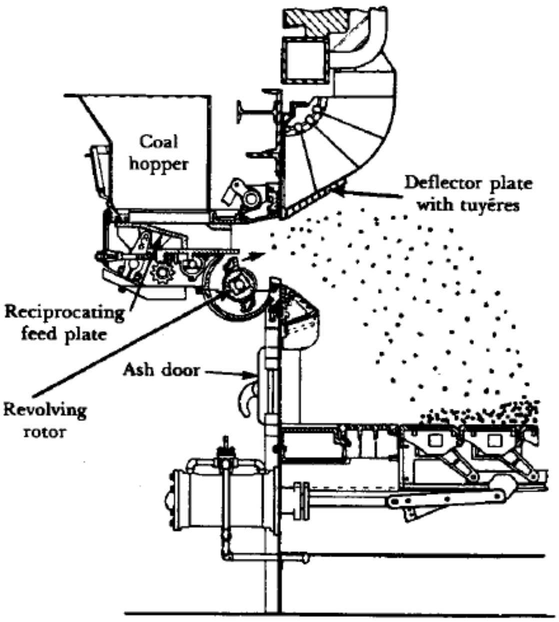
1	Free Hanging Catenary	13	Metering Fuel Air Dampers
2	Alloyed Metal Grate Surface	14	Fuel Trajectory Controls
3	Closed Grate Curvature Design	15	Distributor Deflector Plate
4	Side Door Grate Removal	16	Fuel Distributor Plate
5	Chain Design	17	Overfire Air System
6	Case Hardened Chain Pins	18	Front and Rear Access Doors
7	Full Grate Support Castings	19	Undergrate Access Doors
8	Split Sleeve Bearings	20	Char Recovery System
9	Self-Adjusting Rear Seals	21	Front and Rear Grate Shafts
10	Individual Fuel Chutes	22	Air Pressure Chamber
11	Pneumatic Fuel Distributors	23	Front Undergrate Air Seals
12	Fuel Air Supply Ducts		

Spreader Stokers

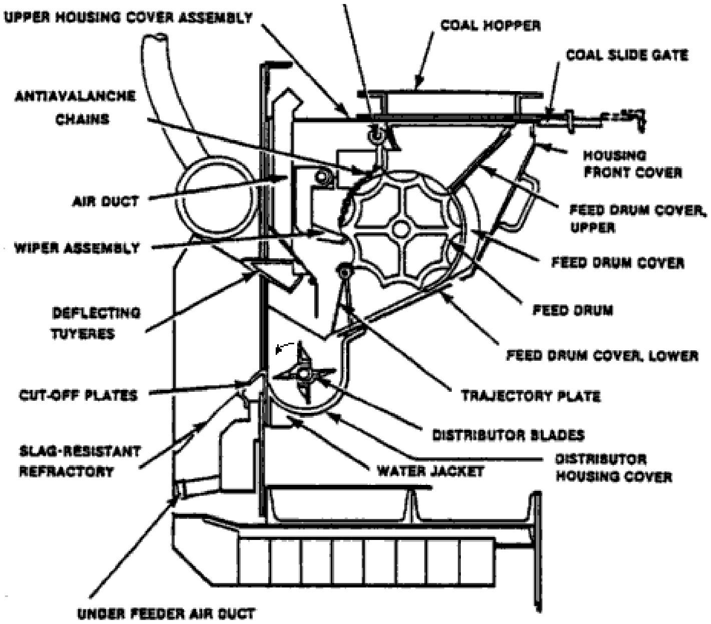
What are the two types of spreader stokers?

Spreader stoker feeders are divided into two classes: overthrow, when the coal comes into contact with the upper part of the rotor blade assembly, and underthrow, when it comes into contact with the lower part.

Steam Plant Operation by Woodruff and Lammers 5th edition page 152-153



Overthrow Spreader Stoker



Underthrow Spreader Stoker

What determines the rate of coal feed into a spreader stoker?

The spreader stoker feeder functions to vary the supply of coal to the furnace and to provide even distribution on the grates. In the feeder-and-distribution system, there is a reciprocating feed plate in the bottom of the hopper. The length of stroke of this plate determines the rate at which coal is fed into the furnace. The automatic combustion regulator varies the length of the feed-plate stroke.

Steam Plant Operation by Woodruff and Lammers 5th edition, page 151

How is the feed plate regulated on a spreader stoker?

The feed plate (fuel gate) is adjustable to suit the fuel sizing and is adjusted up and down by an external adjusting screw. Clockwise raises the plate for larger size coal and vice versa.

Detroit Edison Steam Course "Fuel Burning Equipment" page 55

What is the purpose of a spiller plate?

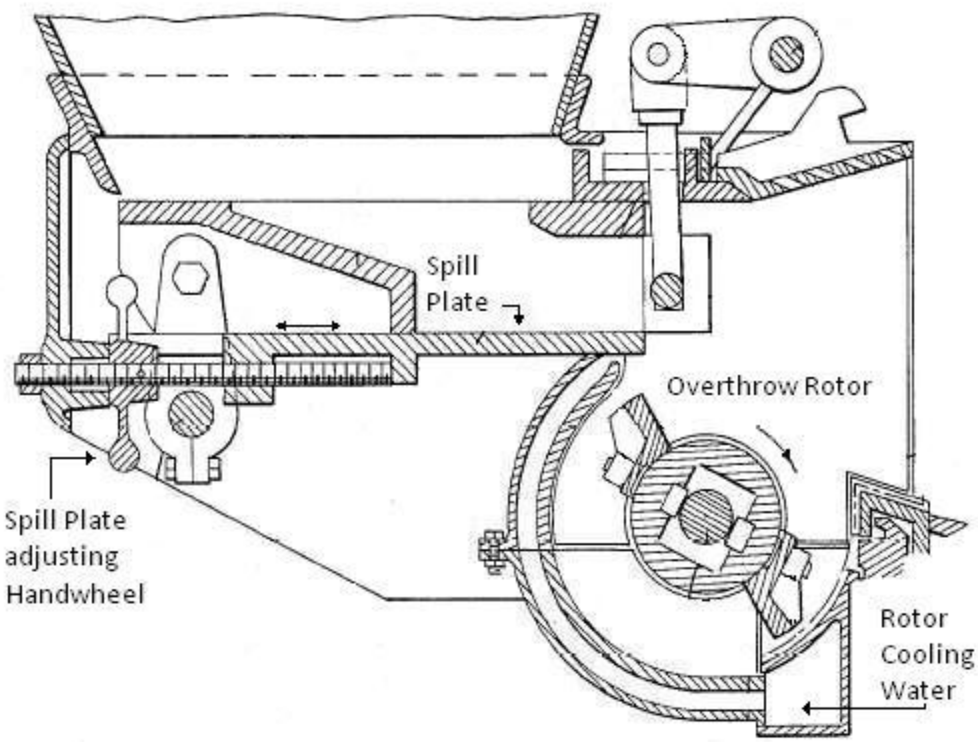
The purpose of the spiller plate (trajectory plate) is to control the trajectory of the coal, either high or low depending on its position in relation to the rotating distributor’s center line.

Detroit Edison Steam Course "Fuel Burning Equipment" page 55

What does adjusting the spilling plate on a spreader stoker accomplish?

The in-and-out adjustment of the spilling plate changes the point at which the coal comes in contact with the rotor blades. Moving the spilling plate back from the furnace allows the coal to fall on the rotor blades sooner. The blades impart more energy to the coal, and it is thrown farther into the furnace.

Steam Plant Operation by Woodruff and Lammers 5th edition, page 15
Detroit Edison Steam Course - Fuel Burning Equipment page 55



Spreader Stoker Spill Plate

What is the difference between a sprinkler stoker furnace volume as compared to an underfeed stoker?

A sprinkler stoker is another name for a spreader stoker. The furnace volume is necessarily larger in a spreader stoker than an underfeed stoker because more volume is needed to allow the coal to be thrown into the furnace without hitting the boiler tubes or furnace walls. The volatile matter that is burned while in suspension needs to burn fully before contacting the cooling surfaces of the tubes, creating soot.

Volatile content of the coal affects the length of the flame and hence the furnace dimensions. Ample and properly disposed furnace volume must be provided in a spreader stoker furnace to insure completion of the combustion process before the boiler surfaces are reached

Blue Combustion Engineering page 5·9

Before satisfactory results can be obtained from spreader stokers, you must provide sufficient furnace volume to provide more flame travel. Therefore spreader stokers use the open furnace design with water cooled walls. Chain grate and traveling grate stokers use a combination of front arch or rear arch design that reduces furnace volume."

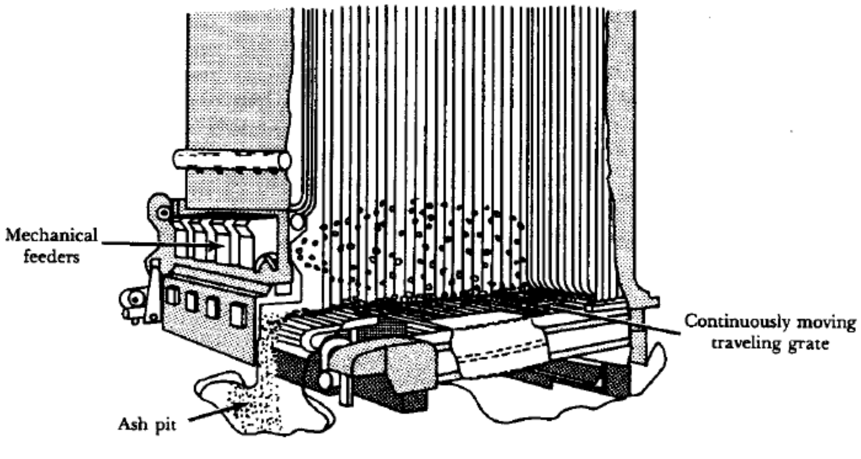
Blue Combustion Engineering page 9·20

Sprinkler stokers are designed for firing small size coal. The fuel is sprinkled or showered on the grate. Distillation of its volatile constituents is presumed to be effected rapidly enough to prevent covering the grate with green coal, and thus the surface of the fire bed is continuously hot. These stokers handle successfully most kinds of coals.

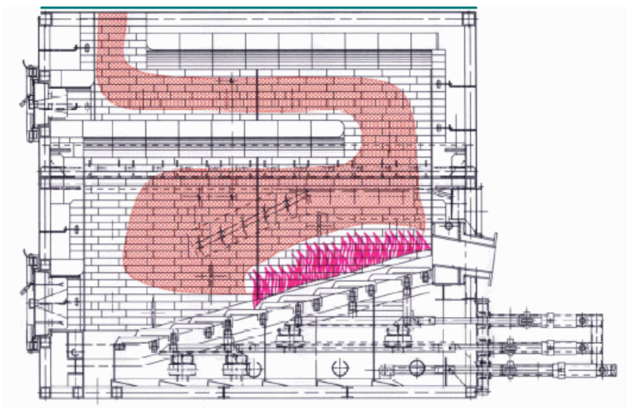
Croft Steam Boilers, page 232

The underfeed stoker requires no fire-brick arch and the combustion space required is less than for any other type of stoker.

Steam Boilers by Edward Marvin Shealy copyright 1912 Underfeed Stokers page 190



Spreader Stoker Furnace



Underfeed Stoker Furnace

What type and size of coal should a spreader stoker use?

Consideration must be given to size when selecting coal for use on a spreader stoker. A distribution of size is helpful in obtaining a uniform depth of coal on the grates. The largest pieces are thrown to the rear, while the fine particles are deposited in front. The size of the largest pieces should not exceed 1 and 1/2 inch. Most manufacturers recommend a top size of 3/4 inch with some limit on the amount smaller than 1/4 inch. Fine coal can be burned on these stokers, but the cinder carryover with the flue gas and the associated problems are greatly increased. The spreader stoker will burn a wide range of fuels varying from lignite to semi-anthracite.

Steam Plant Operation by Woodruff and Lammers 3rd edition page 159

The fuel bed consists of a thin, level fire on top of a uniform layer of ash. Of greatest importance is fuel sizing. The thin quick-burning fuel bed requires a relatively small sized fuel. Larger lumps fall to the grate, and if too large, they cannot be completely consumed during the short burning down time. As a result the carbon loss in the ashpit refuse will be high. This loss may be minimized by holding the maximum screening size to 3/4 inch or less. The stoker will burn fuel ranging from slack all through 1/8 or 1/4 inch screen, to 1 1/4 or 1 1/2 inch nut and slack. Considerable range in size consist is necessary for satisfactory distribution.

Blue Combustion Engineering page 5·7

The larger particles are more easily thrown to the rear of the furnace than the smaller particles. In order to obtain a uniform depth of bed on the grates the coal should have a top size of 1 1/4 inch by 3/4 inch with not more than 40 percent able to pass through a 1/4 inch mesh screen. The more fines, the more suspension burning and the higher the percentage of ash and combustible carried from the furnace by the gases.

Steam Plant Operation by Woodruff and Lammers 5th edition page 157

Note: Spreader stokers may burn all grades of bituminous coal and sizes from 1/8 to 1-1/2 inch nut, the above information is the ideal. Spreader stokers were designed to burn lower grades of coals with high ash content and the low ash-fusion temperature.

Which stoker burns the widest variety of coals; the chain grate, the underfeed stoker or the spreader stoker?

An outstanding characteristic of the spreader stoker is its ability to burn satisfactorily a wider range of fuels than any other design.

Blue Combustion Engineering page 5·5,

Spreader stokers have a wide application with respect to both the fuel that can be handled and the boiler sizes to which they can be applied. A wide variety of coal can be burned on a spreader stoker, but the variation must be considered when the unit is specified. It is inadvisable and uneconomical to provide a stoker which will burn almost any coal in a location where a specific coal is available. In addition to coal, spreader stokers are used to burn bark, chips, and many other kinds of by-product fuels.

The partial list of refuse material suitable for use as fuel includes municipal solid waste, bark, bagasse, wood chips, sawdust and shavings, and coffee grounds

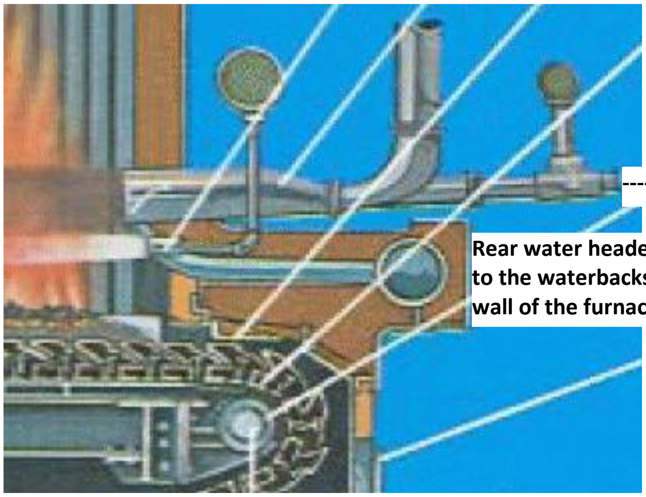
Steam Plant Operation by Woodruff and Lammers 4th edition, page 171

Explain how cinder re-injection works.

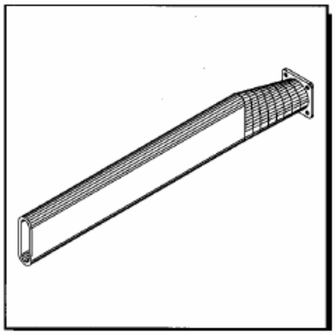
It is customary to collect a large portion of cinders in hoppers beneath the boiler passes and in dust collector hoppers and return them to the furnace for reburning. Cinders removed from the bottom of a stoker furnace have combustible content of 4 to 8%. Cinders carried from the furnace with the gasses contain 40 to 60% combustible. A high pressure stream of air is used to remove the cinders from the hoppers and blow them into the furnace, preferably through a number of openings in the rear wall. The necessary air is delivered by high pressure blowers referred to as the total air required for combustion and, in addition to returning cinders, also supply a system of overfire air jets. The reinjection of cinders in a spreader stoker increases the efficiency of the unit by 3 to 5%, but the practice introduces operation and maintenance problems which limit the extent to which it is advisable to seek the added efficiency. High dust concentrations in flue gasses are abrasive and cause slag and clinker problems.

Steam Plant Operation by Woodruff and Lammers 3rd edition page 157

Cinder Reinjection nozzles


Overfire air jet
Cinder reinjection nozzle
----Air injection for cinders
Rear water header connected to the waterbacks on the rear wall of the furnace

Traveling grate on a spreader stoker. The Cinder Reinjection Nozzle pipe is connected to a hopper with a centrifugal separator to allow the flue gas to head to the chimney while the cinders drop to the bottom of the hopper and are reinjected into the furnace.



New KE Cast Steel Cinder Return Nozzle

Provisions must be made to recover this combustible material in order to reduce air pollution and to reclaim the BTU content of the carbon cinders. A large portion of these cinders are collected in hoppers beneath the boiler passes and in dust-collector hoppers then returned to the furnace for reburning. A high pressure stream of air is used to remove the cinders from the hoppers and return them to the furnace, usually through a number of openings in the rear wall. The blower is called an "over-fire air fan". It is sized to deliver approximately 10% of the total air required for combustion and, in addition to returning cinders, also supply a system of over-fire air jets.

Steam Plant Operation by Woodruff and Lammers 3rd edition page 157

What percent efficiency can be obtained from proper cinder reinjection?

Particulates leaving the furnace contain a substantial quantity of carbon: enough that boiler efficiency can drop as much as 7%. Up to 85% of this 7% loss can be recovered through proper cinder reinjection.

Therefore 6% of total boiler efficiency can be obtained.

Power Plant Engineering page 3.106

The reinjection of cinders in a spreader stoker increases the efficiency of the unit by 3 to 5%, but this practice introduces operating and maintenance problems which limit the extent to which it is advisable to seek the added efficiency.

Steam Plant Operation by Woodruff and Lammers 4th edition page 169

What is the percentage of combustible matter left in cinders from a spreader stoker?

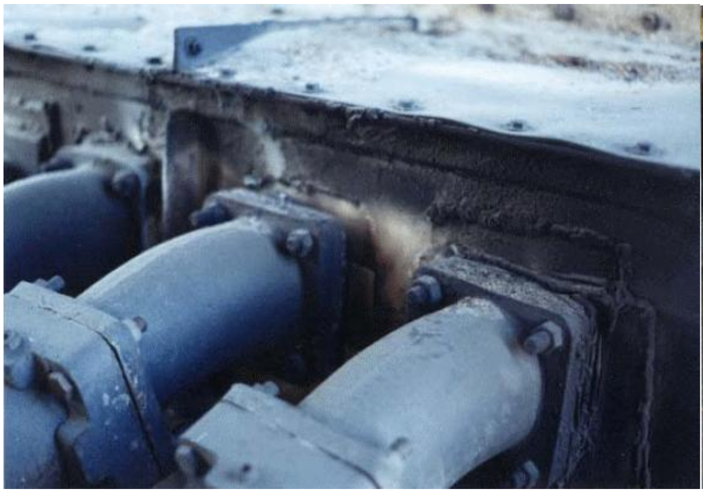
These cinders contain from 40 to 60 percent combustible and therefore represent an appreciable heat loss.

Steam Plant Operation by Woodruff and Lammers 5th edition page 155

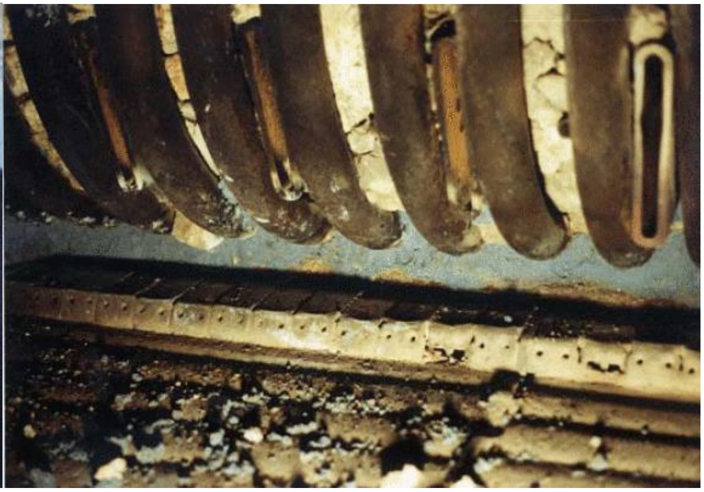
How is the combustible in cinders reclaimed in a spreader stoker?

These cinders are collected in various parts of the boiler and breaching, and collected in cinder hoppers then high pressure air is introduced through the rear wall and used to inject these cinders into the furnace.

Steam Plant Operation by Woodruff and Lammers 5th edition pages 155-156



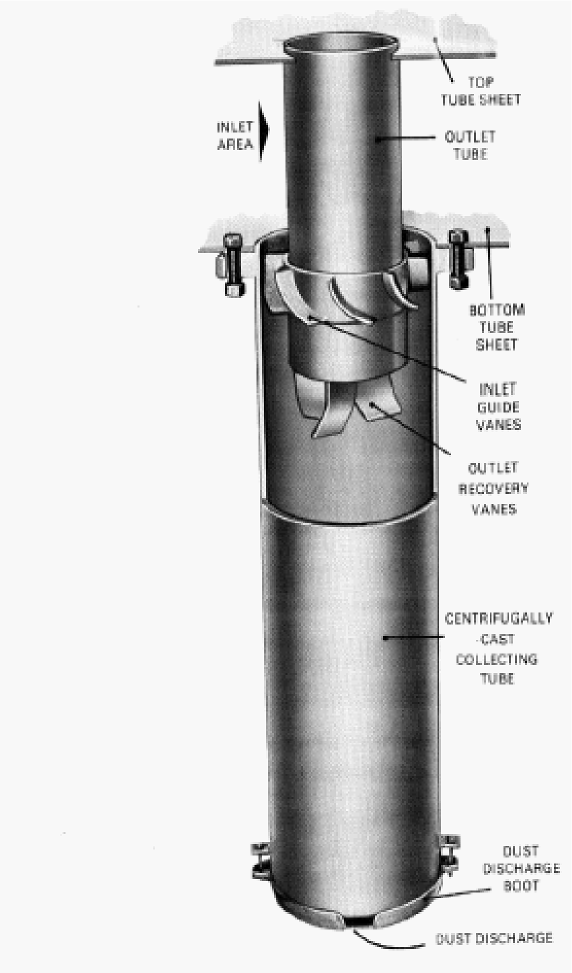
Cinder Reinjection piping on the outside piping of the rear furnace wall



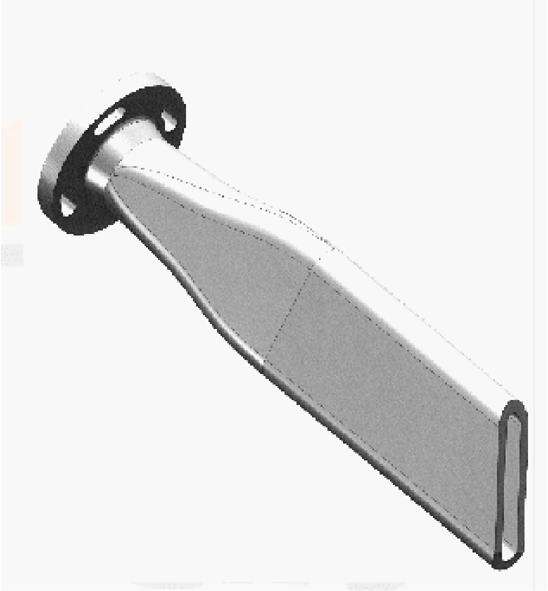
Cinder Reinjection nozzles on the inside of the rear wall between the water tubes. The small holes in the blocks just above the grate are the rear tuyeres where the overfire air comes into the furnace.

How are cinders reclaimed from the flue gas?

The mechanical dust collector illustrated is a multi-cyclone type manufactured by Zurn Industries. The unit has a total of 40 tubes arranged 8 rows across the width of the boiler and 5 rows deep. The ash is collected in two hoppers. The inlet guide vanes give a spinning motion to the flue gas. The flue gas can pass through the cyclone but the heavier fly ash and cinders cannot. The dust discharge boots at the bottom of the collecting tubes feed the hoppers with cinders for reinjection. From the bottom of the hoppers, the cinders are reinjected through the nozzles by a separate fan.



COMPLETE COLLECTING TUBE ASSEMBLY



Reinjection nozzle from the ash hopper to the inside of the furnace.

What problems occur with reclaiming the combustible from cinders in a spreader stoker?

Reinjection in theory increases boiler efficiency, but extensive recirculation of the cinders and ash can result in operating problems. Large quantities of cinders handled by the reinjection system can result in accelerated wear and require replacement of parts. The inert portion of the reinjected cinders retards combustion in the furnace and can result in clinker formation on the stoker grates and slagging of the furnace waterwall tubes. In boilers designed for high velocity gases on the tube passes, the heavy concentration of abrasive ash particles can result in boiler tube erosion.

Steam Plant Operation by Woodruff and Lammers 5th edition page 155

What should the ash content be of coal burned in a spreader stoker?

For best operation, coal on an "as-fired" basis should contain 30 to 40 percent volatile; 5 to 10 percent ash (up to 15 percent on a traveling grate); a heating value of 12,000 Btu/lb minimum; and an ash softening temperature of 2,000 degrees Fahrenheit on traveling grates, but somewhat higher on other bottom ash disposal systems. By special design a wider range of coal can be burned on these stokers.

Steam Plant Operation by Woodruff and Lammers 5th edition page 157

What are the forced draft air requirements of a spreader stoker?

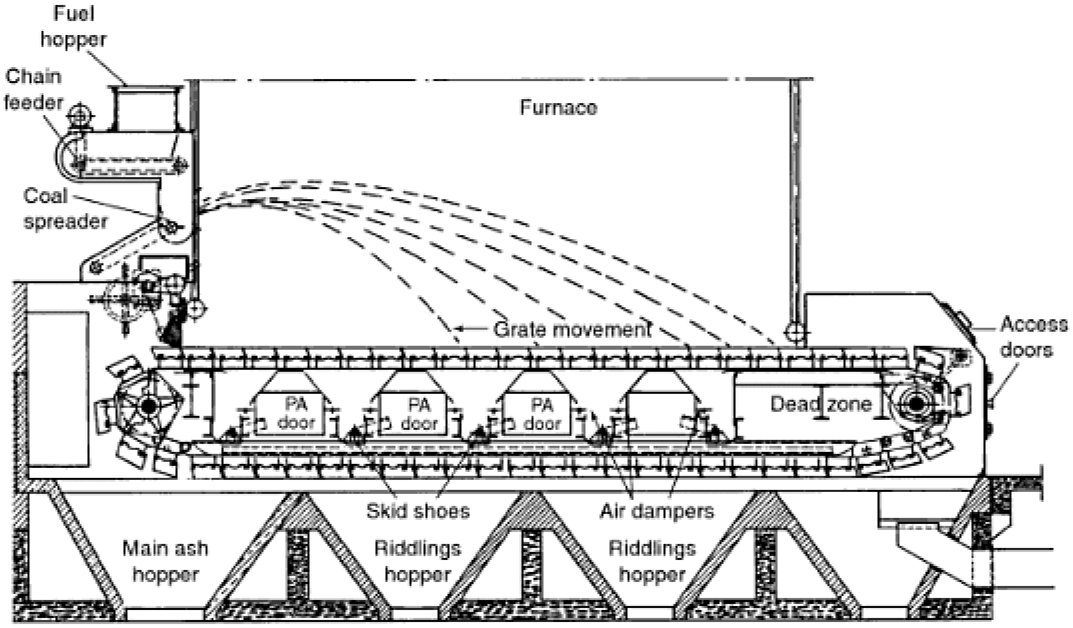
Spreader stokers require a forced draft, at a windbox pressure of 2 to 3 inches of water.

Kent's 12th page 7-71

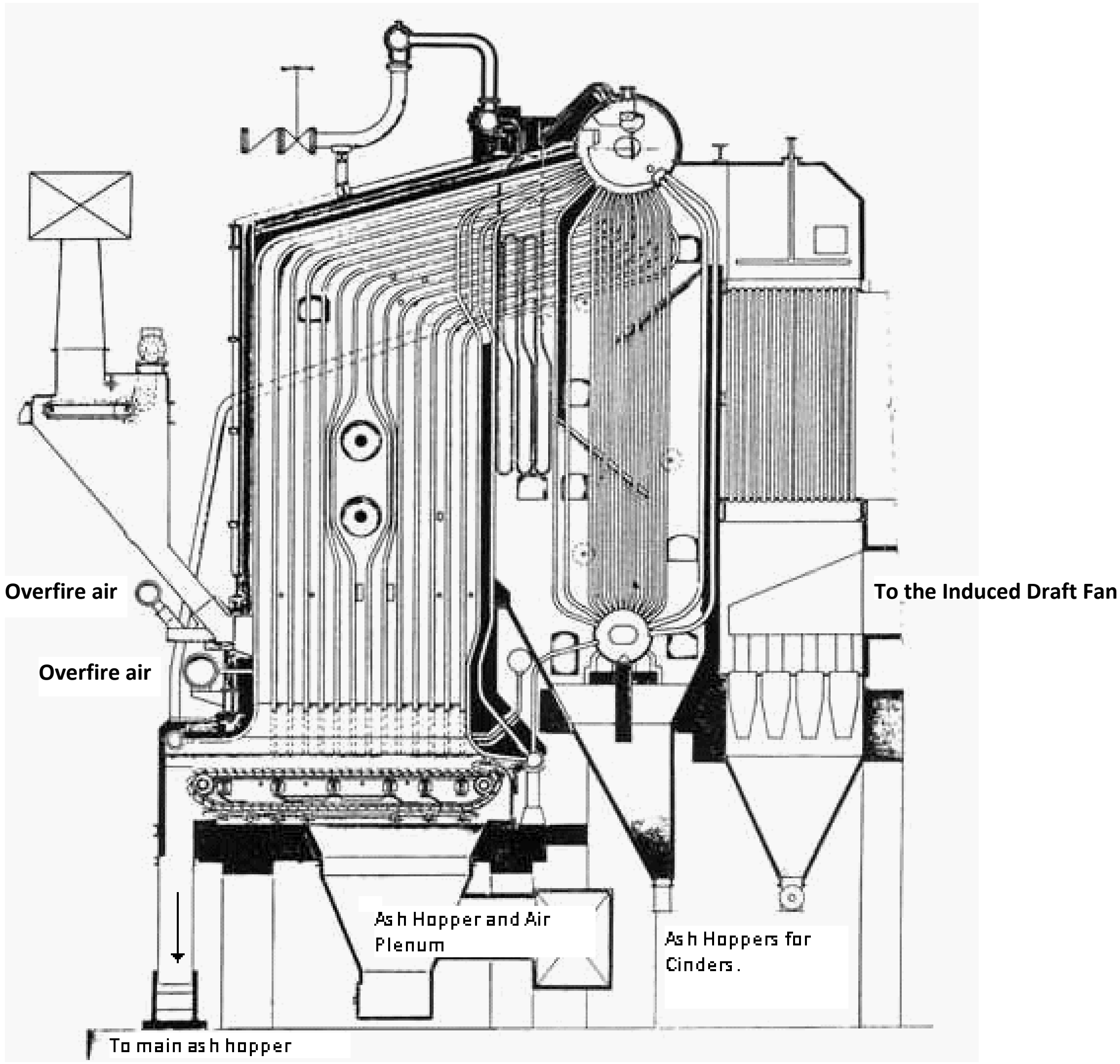
How is air introduced underneath a spreader stoker bed?

A forced draft fan is used to supply air to the fuel through an underrate plenum chamber, which has a damper control. The plenum chamber also serves as an ash pit.

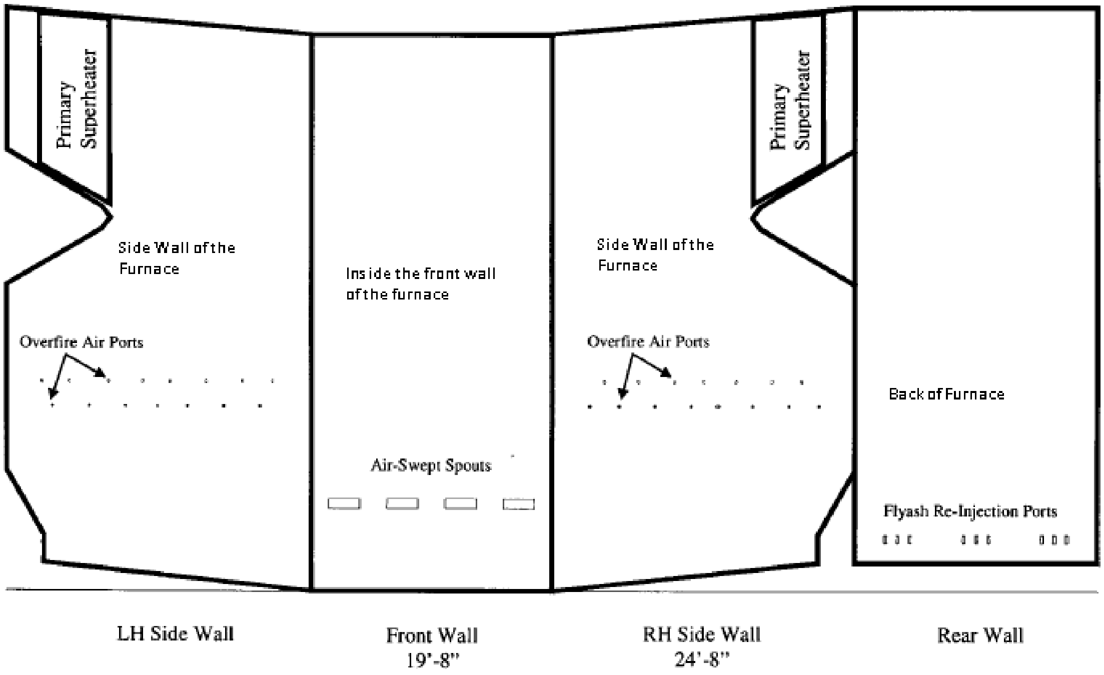
Blue Combustion Engineering page 5·5
Steam Plant Operation by Woodruff and Lammers page 149



The combustion air is introduced through the Primary Air (PA) doors. The air dampers control how much air goes to each section



Spreader Stoker Furnace showing forced air ductwork underneath the traveling grate.



An interesting diagram that imagines the spreader stoker furnace as a paper cut-out that you assemble in your mind. The air swept spouts would be where the coal is sprinkled into the furnace. See if you can visualize the overfire air jets and cinder reinjection from the previous pictures to get an idea of how the furnace is assembled.

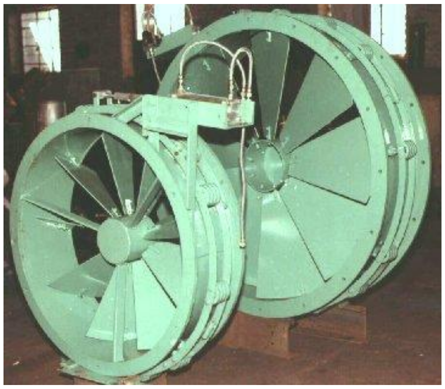
How is draft controlled in a furnace using a spreader stoker?

The draft is controlled by manipulation of two sets of dampers. The induced draft fan inlet and forced draft fan inlet dampers. The induced draft fan damper is opened first then the forced draft fan dampers to prevent pressurization of the furnace. The forced draft fan damper is closed first for the same reason. All dampers are 10% open in the fully closed position. The use of induced draft fan speed control by variable frequency drive can be used instead of dampers.

Operator at Chrysler Sterling Heights Assembly Plant

Variable Frequency Drive

Forced draft and induced draft fan for the spreader stoker

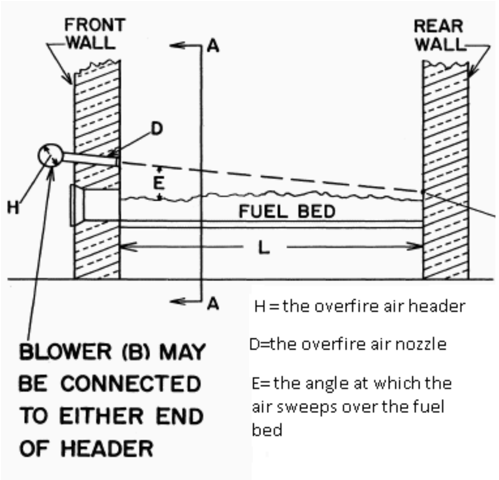


Variable inlet guide vanes for forced and induced draft fans

Explain the purpose of over-fire air.

Over-fire air jets are used to reduce smoke and improve combustion efficiency. These jets consist of one or two rows of closely spaced air jets located above the fuel bed in the front row of the furnace. Bituminous coal-fired boilers are designed with 15 - 25% over-fire air; Lignite-fired boilers are designed with 20 - 25% over-fire air. Refuse-fired boilers are designed with 25 - 50% over-fire air because of high volatile content. The temperature can be either ambient or the temperature of the under grate air.

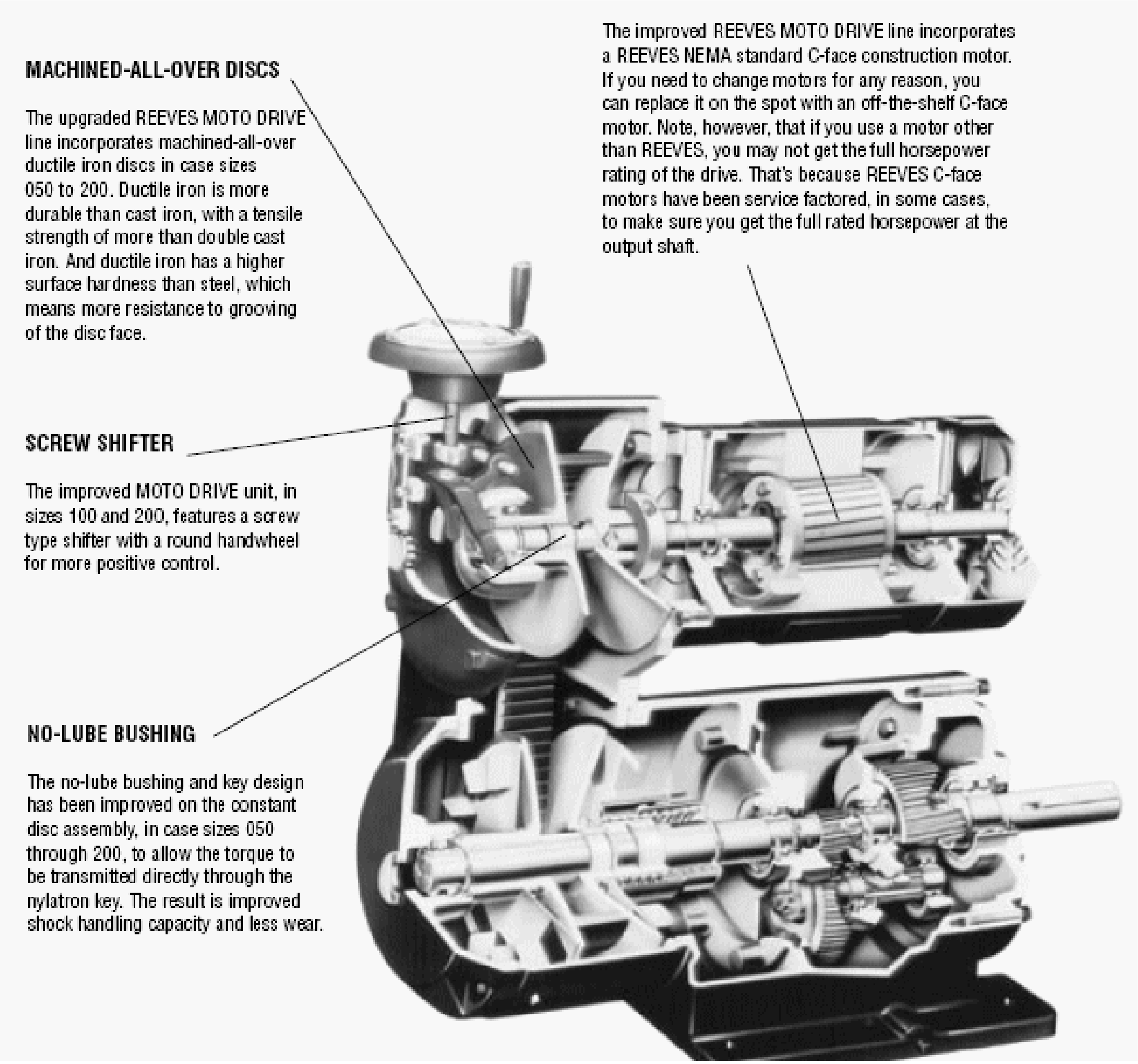
Power Plant Engineering page 1.195
Kent's 12th page 7-71


FRONT WALL
A
REAR WALL
D
E
H
FUEL BED
L
A
H = the overfire air header
D=the overfire air nozzle
E= the angle at which the air sweeps over the fuel bed
BLOWER (B) MAY BE CONNECTED TO EITHER END OF HEADER

Explain a Reeves drive.

A Reeves drive is a system designed to drive and control the rate that the stoker rotors turn and it provides motive force to the gear boxes on the traveling grates of a multiple spreader stoker furnace. The Reeves drive is a common shaft traveling the width of the furnace. Each stoker is clutched separately to the shaft and can be released manually. On the end of the shaft is a spring loaded pulley. A "V" belt rides in this pulley and in a pulley on the motor shaft. A hand crank is mounted to the motor base which raises and lowers the motor. When the motor is raised it pulls the belt deeper into the spring loaded pulley and causes the shaft to turn faster and vice versa. The grate speed is regulated by a gear box on each grate section.

Operator at Chrysler Sterling Heights Assembly Plant



MACHINED-ALL-OVER DISCS

The upgraded REEVES MOTO DRIVE line incorporates machined-all-over ductile iron discs in case sizes 050 to 200. Ductile iron is more durable than cast iron, with a tensile strength of more than double cast iron. And ductile iron has a higher surface hardness than steel, which means more resistance to grooving of the disc face.

The improved REEVES MOTO DRIVE line incorporates a REEVES NEMA standard C-face construction motor. If you need to change motors for any reason, you can replace it on the spot with an off-the-shelf C-face motor. Note, however, that if you use a motor other than REEVES, you may not get the full horsepower rating of the drive. That's because REEVES C-face motors have been service factored, in some cases, to make sure you get the full rated horsepower at the output shaft.

SCREW SHIFTER

The improved MOTO DRIVE unit, in sizes 100 and 200, features a screw type shifter with a round handwheel for more positive control.

NO-LUBE BUSHING

The no-lube bushing and key design has been improved on the constant disc assembly, in case sizes 050 through 200, to allow the torque to be transmitted directly through the nylatron key. The result is improved shock handling capacity and less wear.

On a Reeves drive system, if one stoker stops, do the others stop along with it?

No, each stoker is individually clutched to the shaft and can be released without affecting the other stokers.

Operator at Chrysler Sterling Heights Assembly Plant

Reeves Drive showing the belt drive and adjustable pulleys for speed control

On a spreader stoker, how deep is the ash bed at discharge?

Firing rate of any stoker is controlled to maintain a 3 to 6 inch layer of ash on the grate, protecting it from radiant heat. Pertaining to stationary dump type grates, ash depth will vary from zero, immediately after the fire is cleaned, to 4 inches or more, immediately before cleaning.

Detroit Edison Steam Course -Fuel Burning Equipment

On the grate of a spreader stoker, what would be considered proper bed thickness?

Bed thickness of 3 to 6 inches with 50% fines if coal is tempered about 3%, to prevent siftings. A fast moving thin bed is most efficient. Tempering means adding water to the coal.

Detroit Edison Steam Course "Fuel Burning Equipment"

How many minutes supply of coal is on the grate of a spreader stoker?

The bed is flat and thin and therefore only contains a three minute supply of coal on the grates at any time.

Instrumentation and Controls by Kallen page 9-42

Under proper conditions, there is never more than a few minutes supply of coal on the grate.

Blue Combustion Engineering page 5·6

On a spreader stoker, how close to the back of the furnace is the coal thrown? Why?

On a spreader stoker there are rows of tuyeres along the back of the furnace. These tuyeres are almost flush with the grate where the grate travels up and they form the lower section of the rear furnace wall. The air from the wind box is forced through the tuyeres at a 45 degree angle downward to the grate surface. The purpose is to provide over-fire air to increase turbulence above the fuel bed. The coal is thrown just up to the tuyeres as close as possible without covering the tuyeres. With the tuyeres covered air flow would be restricted. Throwing coal 6 to 8 inches from the rear wall is recommended to prevent slag formation on the rear furnace wall.

Operator at Chrysler Sterling Heights Assembly Plant

Rear tuyeres at the rear furnace wall

On a spreader stoker, what type of grease is used?

A synthetic grease rated for to 400 degrees Fahrenheit + is used. These greases are made from standard soaps, with synthetic lubricants such as esters, organic ethers and silicones in place of mineral oil. Most of these have little or no effect on natural or synthetic rubber. They are produced in both water-soluble and insoluble types.

Stoker Operating Manual for Chrysler Sterling Heights Assembly Plant and Operator at Chrysler Sterling Heights Assembly Plant

Describe how a spreader stoker distributes coal on the grate

A variable speed pulley, also mounted on the motor shaft, drives the distributor and, at the same time, provides means for regulating its speed. The distributors speed is manually controlled since it needs adjustment only when there is a major change in fuel size consistency. The distributor consists of a rotor on which are mounted four rows of blades properly shaped to assure uniform spread of fuel over the grate. The fuel is measured out by the feeder at a rate necessary to carry the boiler load. It then falls in a practically continuous stream into the path of the revolving distributor blades (overthrown or underthrown). Distribution to the grate may be modified by a built-in adjustable baffle which determines the fuel trajectory as it is fed into the distributor, and by the changes in distributor speed which in turn regulates the distance over which the fuel is thrown into the furnace.

Blue Combustion Engineering copyright 1949 page 5·4

How high can you preheat combustion air to a spreader stoker?

Combustion air may be as high as 350 degrees Fahrenheit

Kent's 12th page 7-71
Steam Plant Operation by Woodruff and Lammers 5th edition page 158

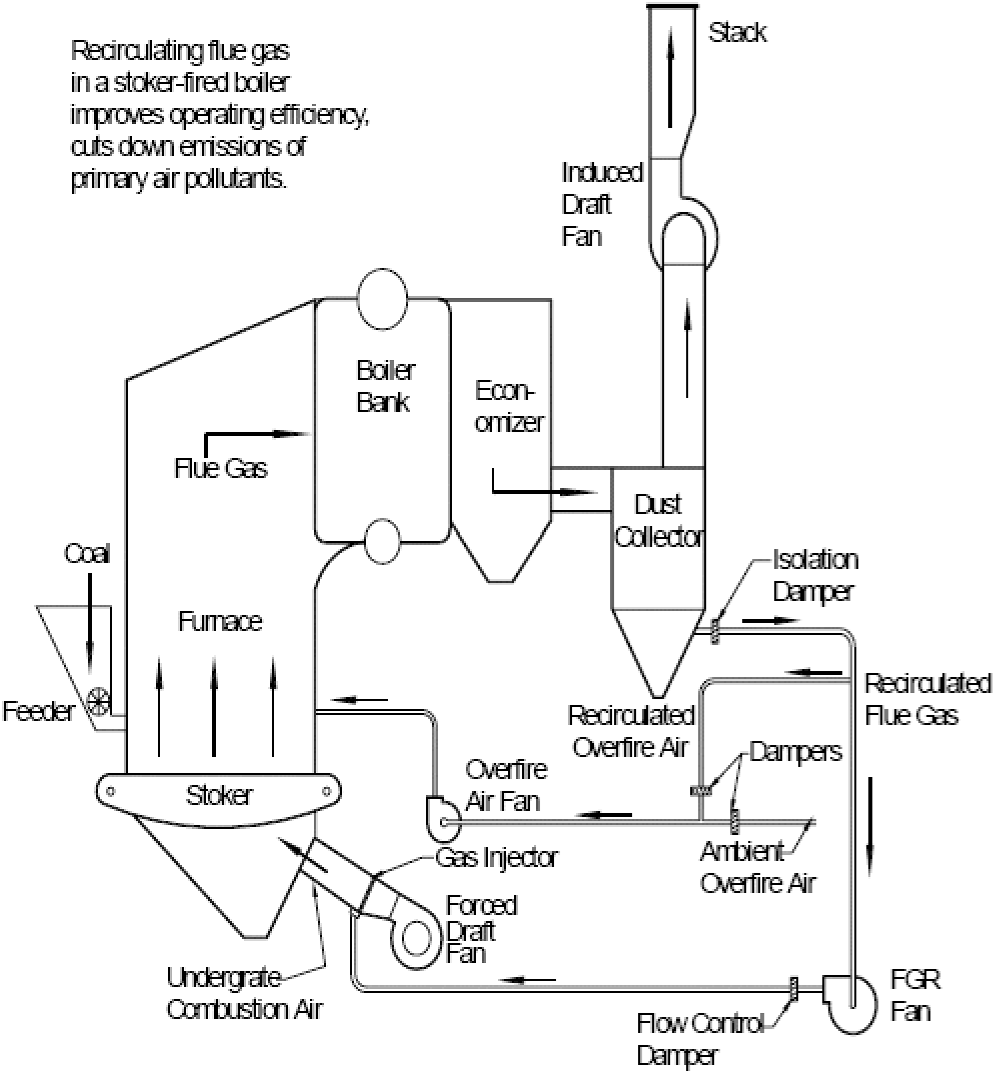


Diagram showing the air flow through a spreader stoker. If this boiler had cinder reinjection, it would take the cinders from the economizer hopper. Sometimes they reinject cinders from the dust collector but whether the extra erosion is worth the BTU's gained in up to the designer of the boiler and operating experience. Note that there are 4 separate fans in this system. There would be a 5th fan below the economizer to reinject the cinders. Flue gas recirculation is done in an effort to lower emissions.

Explain the operation of placing a spreader stoker on line.

Turn on rotor cooling water.

Start to feed coal so it falls on the front half of the grate, build up a two foot pile in front of each stoker. Through the front doors, take oily rags on a long stick and light them and force them into the piles so a wick is formed. Occasionally start the stoker and toss coal on the grate just behind the piles. When a good fire is established, take a rake and start pushing the piles back to spread out the fire. (Be careful of flare backs.) Toss more coal on the grate. This procedure lasts about one hour so the boiler will come up rather quickly. Open the dampers to the wind box. Start the induced draft fan then the forced draft fan. Toss more coal out. Increase draft. Open air through the rear tuyere bank. Start cinder reinjection or the hoppers will fill up and plug the tubing. Start traveling grates if used. Boiler will come up very quickly so get ready to cut back on line. Monitor draft, coal feed and grate speed.

A portion of the volatile matter and of the fine particles in the coal burn in suspension and the remainder falls to the grate, where combustion continues. Air enters the furnace through the openings in the grates. A portion of this air is used to burn the thin layer of fuel on the grates and the remainder passes into the furnace where it is utilized to burn the volatile matter and fine particles. The spreader system is designed to distribute the coal evenly over the entire grate area.

Operator - Chrysler Sterling Heights Assembly Plant

STARTING A SPREADER STOKER

1. Spread coal evenly over the grate to a depth of approximately 1 inch

2. Spread kindling over the coal surface and ignite

3. Start the fans with a low draft

3. Start the stoker spreaders at low speed

4. As the fuel ignites, the fan speeds or dampers are adjusted to supply sufficient air for combustion of approximately .1 inches of water in the furnace and slowly warm up boiler

5. Start the travelling grate just before the boiler comes on line

6. With bituminous coal, ash runs from 3 to 5 inches

7. Start the cinder reinjection fans when the coal is being fed

BANKING THE SPREADER STOKER

1. Reduce the coal feed and air supply until the boiler is no longer supplying steam

2. Stop the travelling grate before any portion of the grate is bare

3. Shut off all fans

4. Feed enough coal to cover the entire grate to a depth of 1 inch

5.Leave the outlet damper open only enough to carry off the gasses

6. To start up from a banked position, overfire air is admitted and the grate is started.

7. Draft, air supply, and coal feed are manually increased until a normal load is established and the automatic control is placed into service

Steam Plant Operation by Woodruff and Lammers 5th edition, page 150

EMERGENCY SHUTDOWN

1. Shut off the coal feed to the bed

2. Shut off the air supply to the furnace

3. This reduces the burning rate to practically zero due to the small amount of coal on the grate

Detroit RotoGrate Stoker Brochure

COAL FIRED OPERATING INSTRUCTIONS

PREPARATION FOR STARTING THE FIRE

Before starting the stoker, grease all lubrication points with the specially compounded lubricants supplied with the stoker. Refer to the various individual sections of your manual and the drawings or photos for the proper locations of lubrication fittings. Insure that all gear reduction units have been properly flushed and filled to the levels, as indicated in the appropriate section of this manual, using the lubricants supplied or those recommended by the instructions.

NOTE
Reduction gear units for new stokers are shipped without lubricant fill, and must be filled prior to start-up.

Caution
Do not attempt to service or repair this equipment while system is in operation. Shut off all power and lock out electrical switches before proceeding to open access doors or remove drive guards. Do not attempt to operate equipment while drive guards are removed or access doors are open.

It is very important that the front drive shaft bearings and the idler sprockets on the rear grate shafts be cleaned and, if required, thoroughly lubricated before starting. Using the "high temperature grease" supplied with the stoker, and a high pressure gun, grease all front and rear bearings at the lubrication fitting manifolds with as much grease as necessary to force the lubricant into each leg. To check this, the front bearings can be observed by opening the grates at the front shaft through the firing doors. A more thorough, and recommended, procedure for this inspection is to remove three grate bars from each grate section at the front sprockets, since the bearings will be more visible through the larger opening. The rear idler sprockets may be observed by entering the air plenum chamber through either side access door between the upper and lower grate strands.

Inspect the grates, both above and below, for any foreign material, such as loose nuts, bolts, nails, wood, refractories, etc. Check all grates to assure the air holes are free and open and all cotter keys in the grate pins are spread and properly wrapped around the pins so the grates are free. Insure that the grates close properly and the upper front grate guides and weights hold them closed as they pass over the front sprockets and as they pass the end of the lower front grate guides.

If furnished, check all reinjection piping and hoppers for foreign materials and debris. Lubricate all auxiliary equipment, such as fans, motors, turbines, et:, as recommended by the respective manufacturers. (Refer to these instructions, as provided in this manual, under the appropriate listing.)

If furnished, silent chain drives (not grate chains) should be lubricated with a good grade of SAE 30 mineral oil for operating temperatures 40º Fahrenheit to 120º Fahrenheit.. For lower temperatures, use SAE 20, and for higher temperatures, use SAE 40.

Inspect the front refractory wall and piers to insure the contour of each is as shown on the detail drawing. Improperly constructed refractory piers will cause the fuel to be distributed unevenly on the grates.

Inspect the apron tuyeres under the coal feeders to see that all air ports are open and free of debris, such as wood or refractory pieces.

Inspect the rear tuyeres to make certain they are clean, with the air holes open so that they move freely and do not bind as the grates pass under them.

For instructions concerning proper inspection, servicing, and lubrication of fuel feeders, distributors, motors, gear reducers, grate drive components, etc., refer to those individual sections of the manual. Prior to starting the stoker, be sure to follow these instructions to prevent any damage to this equipment and the grate system. Where water cooled bearings are provided, assure that the cooling water is being properly circulated to each bearing jacket. Hydraulic drive systems, if furnished, should be inspected for leaks and proper adjustment of control components. Refer to sections of these instructions for flushing of hydraulic power units and piping and the recommended adjustments of valves and controls.

Check all motor driven items to insure the motors are rotating in the proper direction. The RotoGrate stoker employs a forward traveling grate to continuously discharge ash residue into the front ash pit. The front shaft sprockets driving the grate chains must always rotate so that the top of the sprockets and front drive shaft move forward away from the rear of the stoker. This will allow the top strand of grates and fuel bed to move forward.

NOTE:

The grate drive should not normally be operated in reverse as damage to seals; guides and grate assembly will occur due to jamming of the open grate bars at these points. Short 1" to 2" reversing of the grates may be possible in the event it is necessary to clear an obstruction.

The allowable reverse distance will be determined by the actual position of the open grate bars in the lower catenary strand.

Upon determining that all motors are rotating in the proper direction, check all mechanical drives, if provided, to assure shear pins are properly inserted, using only Detroit Stoker Company shear pins designed for the proper applications. This will insure that the warranty will remain in effect.

NOTE

Refer to "Grate Drive" and "Feeder Drive" sections of this manual for locations and applications of drive protection devices.

If your RotoGrate is equipped with an auxiliary drive unit, be sure it is mechanically disengaged before starting the main drive unit.

Caution:

Do not attempt to service or repair this equipment while system is in operation. Shut off all power and lock out electrical switches before proceeding to open access doors or remove drive guards. Do not attempt to operate equipment while drive guards are removed or access doors are open.

By starting the grate drive for short intervals, check all upper and lower front air seals, and the rear coking sections, if provided to assure the grates have free movement, do not bind, and there are no "jerky" movements. When it has been determined there are no obstructions, start the grate drive and operate continuously for several hours to "wear in" the seals and guides. This will eliminate any minor interferences to free movement. (For adjustments to grate drive speed controls, refer to the "Grate Drive" instructions in this manual.)

Check the settings of the combustion controls and linkages to grate drive, fuel feeders, forced draft fan, and overfire air fan by referring to those sections in your manual, assuring that the actuators will properly stroke the controls from minimum to maximum positions without overriding in either direction. The actual undergrate air pressure cannot be predetermined, however, the pressure in the plenum under the grates could vary from less than 0.05" to more than 2.0" water column, dependent on load and fuel characteristics. Similarly, settings for air pressures at the various headers and nozzles of the overfire air system cannot be predetermined and, thus, all air pressure settings will require adjustment during start-up. In the event that there is a change in fuel purchased, it may be necessary to revise the air settings correspondingly.

STARTING THE FIRE

If your RotoGrate Stoker is equipped with an auxiliary drive unit, be sure it is disconnected prior to starting the main driver. Check all coal feeder fuel hoppers and the coal supply system to insure they are free of foreign materials and debris. Start the coal feeder drive, or drives. (Do not start, or engage, the grate drive at this point.) The feeders should be started with the feed control set at the "minimum" position. The feeder rotors should be running before coal is supplied to the hoppers to prevent coal from filling the rotor pans and possibly jamming the rotors. After all feeders are started, and all of the rotors are operating at the same speed, the feeder control should be set to feed coal and operated just long enough to spread an even fuel bed on the grates to a depth of approximately one or two inches. When an even fuel bed is obtained, disengage and stop the coal feeders.

Caution:

Before performing any maintenance or inspection inside of the combustion chamber, shut off, and lock out, all electrical supply to grate drive, fuel feed equipment forced draft fan and overfire air fan. Insure that the combustion chamber has been cooled sufficiently, all combustible fuel and ash has been discharged and proper ventilation is provided inside the chamber for tire working personnel. Close off all fuel supply chutes leading to the combustion chamber to prevent material from falling on personnel when inside the combustion chamber.

Pile kindling wood, free of nails and wire, and several oil soaked rags over the coal bed on the grates and light the fire with a torch through the firing doors.

After a good burning fuel bed is established over the entire grate, check the fuel bed for coal distribution by observing through the observation sight glasses in the side welts.
Caution:

Do not enter the combustion chamber when the fuel feeders are operative nor enter the combustion chamber to light the fire. Do not light the fire using any highly volatile liquid similar to gasoline or kerosene. Dangerous explosions will occur, within the combustion chamber, resulting in serious personal injury and damage to the equipment

As soon as the fire is ignited, close the furnace access door and re-start the feeder drive to allow rotors to turn without feeding coal. If a cinder return (fly carbon reinjection) system is installed, the high pressure fan serving this system should be started when the fire is ignited, otherwise the hot furnace gases will "short circuit" in reverse through the cinder return piping, and possibly damage them. Set fan air control dampers to the minimum position.

If an induced draft fan is employed, start the fan and allow the draft controls to open the combustion unit outlet damper to maintain a negative furnace pressure of approximately -0.15" water column. Open the forced draft fan damper, as well as the stoker "blast gate" to the air plenum, to its normal operating position to provide a free flow of draft induced undergrate combustion air.

When the wood fire is burning briskly, add coal to the fuel bed, a little at a time, by engaging the fuel feeder occasionally, until all of the coal on the grates has been ignited and is burning freely. At this point, the fuel feeders may be fully engaged and the forced draft fan started with air damper set at minimum position. Increase the fuel feed and air gradually, being careful not to overload the fuel bed, until a clean, brisk fire is obtained over the entire grate area. If excessive smoking is observed during the start-up period, reduce the amount of coal being fed to the grates until the condition is corrected.

NOTE:

A cold combustion chamber will have a tendency to create a smoking condition until the chamber temperature is raised above the fuel ignition temperature.

Caution:

Do not attempt to observe active fuel bed or combustion chamber through an open access door. Serious personnel injury may occur in the event the combustion chamber would become pressurized View all fuel bed or chamber condition, through a glass covered inspection port with safety door.

The fuel should build up evenly on the grates directly forward of the rear tuyeres. Do not allow the fuel to pile on the rear tuyeres. To prevent this, reduce the feeder rotor speed. (Refer to the "Coal Feeder" and "Feeder Drive" sections of your manual for instructions on feeder adjustments.) If coal does not feed rearward as far as the tuyeres, and the rear part of the grates are not fully covered, increased the feeder rotor speed. Feeder controls should be adjusted very little at any one time and at intervals that will allow observation of the effect the last change has made on the fuel distribution.

Upon observation that adequate distribution is being obtained, and when an ash bed has built up on the grate to about 1" or 2" thick, the grate drive may be started. Adjustment of the grate speed is dependent upon toad demand and ash content of the fuel which will determine the amount of ash being deposited on the grates. The grate speed should be set to allow the ash bed to be approximately 3" to 4" deep at the front end, as it is discharged to the ash hopper. If the ash bed is too thin, the grate speed is too fast and should be reduced.

NOTE:

Ash bed thickness may vary considerably from the above dependent upon coal quality and ash content

If the ash is too deep, it will tend to form clinkers and carry unburned coke forward on top of the clinkers. To correct this condition, increase the grate speed slightly at spaced time intervals until the correct ash bed is obtained. During the "start-up" period, it is advisable to operate all of the stoker control components on "manual" and limit the maximum stoker operation to about 40% of rated capacity.

All coal feed and grate speed control linkages must now be adjusted prior to switching the stoker to the automatic control mode. During this adjustment, it will be necessary to make these settings at minimum coal feed, maximum coal feed, and several points and obtain gas samples to determine optimum O2 performance across the entire capacity range.

NOTE:

Refer to various sections which follow in your manual (Coal feeders and grate drive) descriptions of the adjustments required for those items installed on your RotoGrate Stoker.

Detroit RotoGrate Stoker

Recommended Yearly Maintenance Procedures

To take the stoker out of service for yearly maintenance, first stop the grate drive, shut off coal gate(s) above feeders and allow feeder to run all coal out of hoppers. After boiler has cooled, remove the insulation on top of the rear tuyeres and vacuum the space clean. Ash residue left on the grates may be removed by running the grates as soon as boiler is cooled down. After cleaning the insulation from the rear tuyeres, remove the rear tuyeres, clean these and the supports so they will be free to move when reinstalled. Any tuyeres missing or burned should be replaced. Clean all air holes in rear tuyeres.

Remove the rope insulation at side walls. Vacuum this area clean.

Remove four (4) or five (5) grates in each section across on the bottom catenary strand of grates, and start the grate drive. Follow this opening space, as the grate moves, checking for grease to shaft bearings, wear on rails, air seal wear and adjustments, sprocket wear, etc.

Replace the grates removed and check each grate for the presence of a steel washer, left hand or right hand washer, and insure each cotter key is wrapped around the pin. As each one is checked, place a mark for reference until all grates are checked.

Check thermocouple wiring to insure that all are intact. The grate temperature should be close to room temperature at this time.

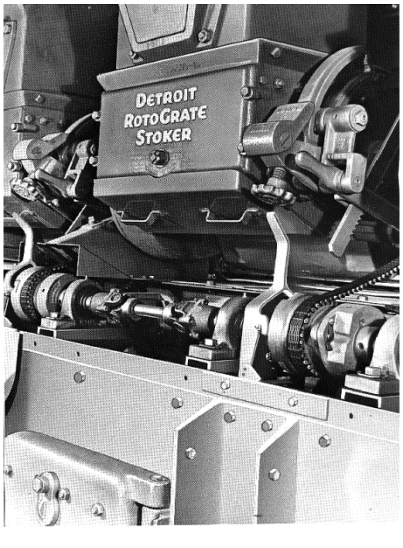
Reinstall rear tuyeres and insulation, Johns-Manville 450 or equal, over 1/3 of the tuyere from back. The insulation should be set just sufficiently to hold together. If it is mixed with too much water and is wet, it will shrink. If it is mixed with ash, etc., it may become too hard. Check to see that all tuyeres move freely.

Run the grates again and clean all air holes with a punch. A drift pin or large nail may be used. Be sure the punch is not so large that it will enlarge the hole. Repack insulation at the side walls.

Refractory and brick work should also be checked and repaired, if required, at this time. Rear wall should be checked for air leakage.

The feeders should be inspected for repairs, replacing any bearings, worn shafts, or other mechanical problem. The part names and numbers may be identified by referring to the service manual or job material list. The feeder drives should be checked for adjustments and possible repairs, as required. Check all feeder rotor blades for tightness and possible replacement, if worn.

IOM-0104 11/25/86 Detroit RotoGrate Stoker



MAINTENANCE CHECK LIST (Coal Fired Stoker)

1. Check grate slide rails. They should not be burned below top level of grates, check especially at the rear.
2. Check for warped grates or cracked or plugged air holes in the grates
3. Check rear tuyeres. Tuyeres must be free to move and packing over tuyere must not be hard. Before repacking, check rear seal plate.
4. Check side air seals. If seals had previously been packed with asbestos rope, it may be necessary to repack with new non-asbestos rope packing.
5. If possible, remove four (4) grates from each section and check rear tuyere support seal plate, rear coking sections and upper and lower front seals.
6. Check rotor blade feeders and replace if worn
7. Check plastic refractory piers and arch and check apron tuyeres for burned castings.
8. Check overfire air nozzles and cinder return nozzles for burned or plugged nozzles.
9. Check lower front grate guides and front slide rails for wear and leakage.
10. Check front grate guides to assure they are holding grates closed as the grates pass over the front sprockets .
11. Check lower strand of grates to be sure grates hang freely and swing easily.
12. Check and clean all flyash hoppers. Clean and inspect all cinder return pick-ups. Inspect dust collector.
13. Check for segregation in coal supply chutes to coal feeders.
14. Check settings and adjustment of each coal feeder. All coal feeders should be set alike.
15. Check feeder mechanism to be sure all feeders are working properly with no excessive free play or lost motion.
16. Check grate variable speed drive.
17. Check blast gate and blast gate linkage.
18. Check entire unit for air leakage, especially check ash pit and ash doors, all stoker and furnace doors. Candle all joints and cracks in setting to check for air leaks. Often points of air leakage will be identified by black discoloration from smoke.
19. With unit in operation, check for high excess air (O_2) at furnace outlet. If air leakage is a problem, it is difficult to obtain good excess air reading at the furnace outlet. Check excess air in the furnace with a water cooled probe.
20. Check distribution of coal on grate. Fuel bed should be level with no high spots or ridges. Fire should be all the way to the rear wall.
21. Check all points of lubrication and add oil to gear cases if required.
22. Check chain and belt drives. chain or belt tension, and lubricate chains. Check for worn belts.

IOM-0105 12/17/86 Detroit RotoGrate Stoker

Stoker Maintenance and Operation, a Vital Marriage

by Stephen M. Hopkins

Detroit Stoker Company

The interplay of the operation and maintenance of stokers is an often overlooked source of inefficiency in plant operations. Maximum efficiency requires coordinated operation and maintenance. Poor operation can create maintenance problems and poor maintenance can create operational problems.

Some plants do not provide the operators with a clear operation plan. The operators are not trained in the theory and practice of good operation. Poor operation, such as running with a thin ash bed can damage the grates or other components, creating work for the maintenance department. Unfortunately, this work is often performed hurriedly or incompletely to get the unit back on line.

It is important to include all aspects of operation in the plan. A common problem is purchasing of coal. A purchasing agent must have clear specifications for the fuel to make cost effective purchasing decisions. A classic example might be the overzealous purchasing agent who buys an inferior or improperly sized coal, based on BTU content per pound per dollar value. In such cases, ash fusion temperature, free swelling index, size consist, etc., may not be compatible with the stoker type installed. As a result, excess air requirements, clinkering, slagging, particulate emissions, fuel distribution problems, etc., may increase to the point where efficiency and maintenance costs will suffer, offsetting any fuel purchase savings.

We have seen plants where operators are asked to maintain output with a minimal or non-existent maintenance program. The "If it ain't broke, don't fix it" theory of operation is a good one, but the trick is knowing when something is broke. Many components of a stoker may be operating, but at such a reduced efficiency that they should be considered 'broke'. Does 'broke' mean the boiler is down, or the cost of maintenance is less than the cost of wasted fuel, extra wear on other components and operator frustration?

The focus of this paper is the need for coordinating operation and maintenance to reduce overall costs. These costs must be examined on a time scale of months and years, not just daily or weekly. It is recommended that the operation and maintenance department regularly discuss the operation and efficiency of the unit with a focus on reducing costs and down time. These discussions are enhanced through a joint operator/ maintenance training session on an annual basis.

The Maintenance Plan

A stoker can be thought of as the carburetor of the furnace. Its' job is to properly mix the fuel and air for maximum combustion efficiency at a variety of loads settings. Unlike the carburetor a stoker must handle a solid fuel and the ash remaining after combustion while withstanding the heat of being the floor of the combustion chamber. Due to these conditions the stoker is subject to much more wear and tear than a carburetor. It follows that a stoker should be periodically inspected for damage and wear, and kept in a condition to allow efficient operation. This is the goal of any maintenance program.

Preventative maintenance such as lubrication should be performed as recommended by the stoker manufacturer. During preventative maintenance any unusual conditions should be noted in a maintenance log and discussed with the operators. The maintenance log should be reviewed as part of the annual inspection.

Inspections should be performed on at least on an annual basis or whenever the unit is down for any reason. The inspection should include a planning session after the inspection to forecast replacement of worn out parts at the current of next outage. The services of an outside consultant should be included at least occasionally or when major replacements are anticipated.

The Operation Plan

A plan for operations should be developed and followed. This plan should include training.

Spreader Stokers:

The spreader stoker uses many links and rods to control the motion of the grates. This system should be properly lubricated to minimize wear and inspected for worn parts on an annual basis. The operators will have trouble maintaining proper bed depth and distribution as lost motion due to wear increases.

Spreader stokers burn approximately 40% of the coal in suspension. The burning fuel bed on the grates is only 1 to 1 1/2" deep. For this reason the spreader stoker is highly responsive to load changes and very forgiving to coal quality as long as the quality is consistently supplied. There is a lower limit to volatile content: 20 to 25% on a dry and ash free basis, and fines should be about 40% by weight. The free swelling index is not a factor on spreader stokers and they are capable of burning coals with lower ash fusion temperatures as compared to mass burning stokers.

Fuel distribution on the grate is highly important since the resulting ash bed is needed to protect the grates from the heat of the combustion chamber. With higher burning rates per square foot of grate area, temperatures are higher and the grates must be adequately protected. Coal segregation in the feeder hoppers can create fuel distribution problems.

Fuel is burned in stages, from front to rear. Variable load conditions dictate a need to frequently manipulate the zone air dampers. This must be accomplished manually, otherwise high excess air quantities at low loads will be experienced, or they may discharge hot materials at high loads. When hot ashes are discharged into ash pits, large clinkers can form and these are difficult to break apart and remove, especially while the stoker is in operation. The result will be unscheduled downtime.

Since there are no provisions available to break apart coke formations on the fuel bed, coals with minimal coking tendencies are most suitable. Tempering the coal, the act of adding moisture to the fuel, will provide some degree of relief for higher free swelling coals but this will create a degree of inefficiency since the heat required for moisture evaporation must be generated by the coal burned.

Coal segregation in the hopper, both to the sides and from front to rear, can also create fuel bed problems.

Where load changes are frequent, operators must be diligent in their attention to fuel bed condition as well as air control.

It is also important that the upper and lower air seals between the zone air compartments and side air seals be properly maintained. If not, there can be high O_2 levels in the flue gas, thus the overall efficiency will suffer.

Boilers and Auxiliary Equipment

Regardless of the type used, most stokers can be operated within acceptable limits of efficiency, provided that the stokers, boilers and associated auxiliaries are properly maintained and fuel quality supplied is constant. If coal handling equipment is neglected and size segregation is the problem, or the coal is degraded when delivered to the stoker hopper, operating problems will occur. When stoker equipment is not properly maintained and seals and settings are permitted to deteriorate, not only will operating problems develop but additional maintenance will be required. Poorly operated and maintained stokers will create further problems with boiler fouling and slagging; increased gas velocities may cause tube erosion and flue gas collection equipment will become overloaded.

Where collection hoppers are allowed to accumulate excess flyash and air leakage is permitted to occur, there becomes the danger of hopper fires.

Good operation will not create additional maintenance and good maintenance will reduce operational problems. The compounding effects of adverse operating and maintenance conditions will result in loss of efficiency and reduced life cycles through the entire boiler island.

Summary

All personnel need to be reminded that, to spell ECONOMY, it requires

Everyday common sense
Continuing education programs
Outside help when needed
Neat and clean plant
Operational procedures
Maintenance programs
Your own personal pride

Stephen M. Hopkins, Manager Instructions and Training
Detroit Stoker Company,

This paper presented at the Thirty-third Annual Kentucky Coal Utilization Conference, University of Kentucky, April 13-14, 1994.

Chapter 9 Pulverizers

Pulverizers

Name the three functions that a pulverizer performs.

The pulverizing mill is the heart of the direct-firing system. The functions of the mill are:
1. feeding raw coal at the proper rate
2. grinding the coal to the desired fineness
3. classifying the finished product so oversized particles are returned to the mills grinding zone.

Flame Safeguard Controls Honeywell page 34

What three functions does air perform in a pulverizing mill?

In most mills, air provides three functions:
1. it dries the coal
2. it helps classify the pulverized coal leaving the grinding elements,
3. it transports the finished product to the burners. The air is supplied by forced-draft or negative pressure.

Honeywell Flame Safeguard Controls page 34.

What properties in coal do you consider when operating a pulverized coal plant?

1. Sulfur may cause corrosion of metal in bunkers and other areas; may promote oxidation and heating in storage; limits air heater exit temperature of flue gas; affect slagging tendencies.

2. Ash content: Reduces handling and burning capacity; may boost handling and maintenance cost; retards combustion and increases carbon loss; involves expense for removal and disposal. More ash means more flyash emission.

3. Ash-fusibility temperature: Influences choice of type of furnace bottom. In relation to furnace temperature, the parameters of fusibility, ash content and composition indicate slagging tendency.

4. Coal size: Influences pulverizer capacity, which is greater with lower grinding cost on smaller sizes. Fines may lead to handling and dust problems.

5. Low-volatile coal: Ignites less readily and requires longer burning time, affecting furnace volume, and location and amount of cooled surface. Burning is improved by preheating primary and secondary air, by low primary-air volume and high furnace temperature.

6. Moisture: Reduces burning and handling capacity; may increase handling difficulty and cost; affects ignition and increases flame length; must be evaporated in furnace, causing a loss. High moisture means more drying in the mill.

7. Grindability: Major coal factor affecting mill capacity; major factor affecting grinding cost and maintenance.

POWER Feb. 1974. pp S-3. Pulverized coal plants rely on fuel properties

Enumerate the advantages and disadvantages of pulverizers.

Advantages:

a. Can change rate of combustion quickly to meet varying load
b. Requires low percentage of excess air
c. Reduces or eliminates banking losses
d. Can be repaired without cooling the unit down, since equipment is located outside the furnace
e. Can be easily adapted to automatic combustion control
f. Can utilize highly preheated air successfully
g. Can burn a wide variety of coal with a given installation
h. Limits use of fine wet coal only through the ability of the conveying and feeder equipment to deliver the coal to the pulverizers

Disadvantages:

a. Is costly to install
b. Requires skilled personnel because of explosion hazards
c. Requires electrostatic fly ash precipitators to reduce stack emissions to acceptable limits
d. Requires multiple mills and burners to obtain a satisfactory operating range
e. Gives difficulty from slag deposits on the lower rows of boiler tubes
f. Requires extra power to pulverize fuel

Steam Plant Operation by Woodruff and Lammers 5th edition page 175

List the advantages and disadvantages of running a pulverizer under a vacuum or under pressure.

Advantages under Vacuum

No leakage of coal dust into plant.

Disadvantages under Vacuum

The fan handles air laden coal which is very abrasive

Advantages under Pressure

The fan handles clean air

Disadvantages under Pressure

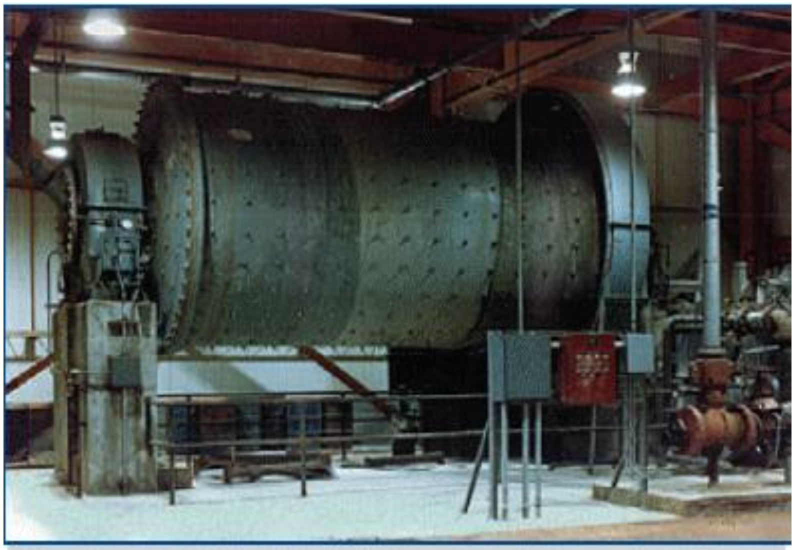
The unit must be kept air tight.
The fan size and power requirements are greater than vacuum systems.

Honeywell Flame Safeguard Controls page 34

What are the different types of coal mills?

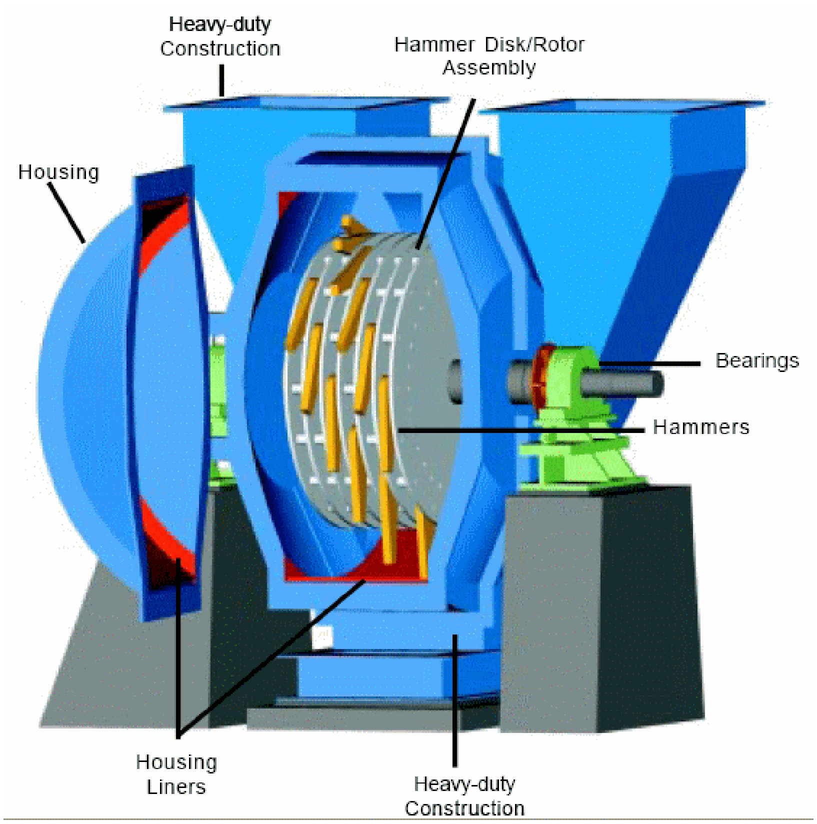
Ball mills consist of a horizontally rotating cylinder less than half full of balls of various diameters from 1 to 2 inches. The speed of rotation is approximately 20 RPM. Balls carried up the periphery in the direction of rotation continually cascade toward the center. Coal mixed with the ball charge is pulverized by impact, attrition, and crushing. Hot air passed through the mill dries the coal and removes the fines. A classifier is used in some designs to regulate the fineness of the finished product by returning the coarser particles. Low maintenance and quick response to change in output rate are characteristics of this mill.

Power requirements, particularly at reduced capacity, are relatively high. Space requirements are relatively large for a given capacity, and with wet coal there is an extreme falling off in capacity. The large storage and heat capacity makes this type of mill poorly adapted for intermittent operation or quick starting.



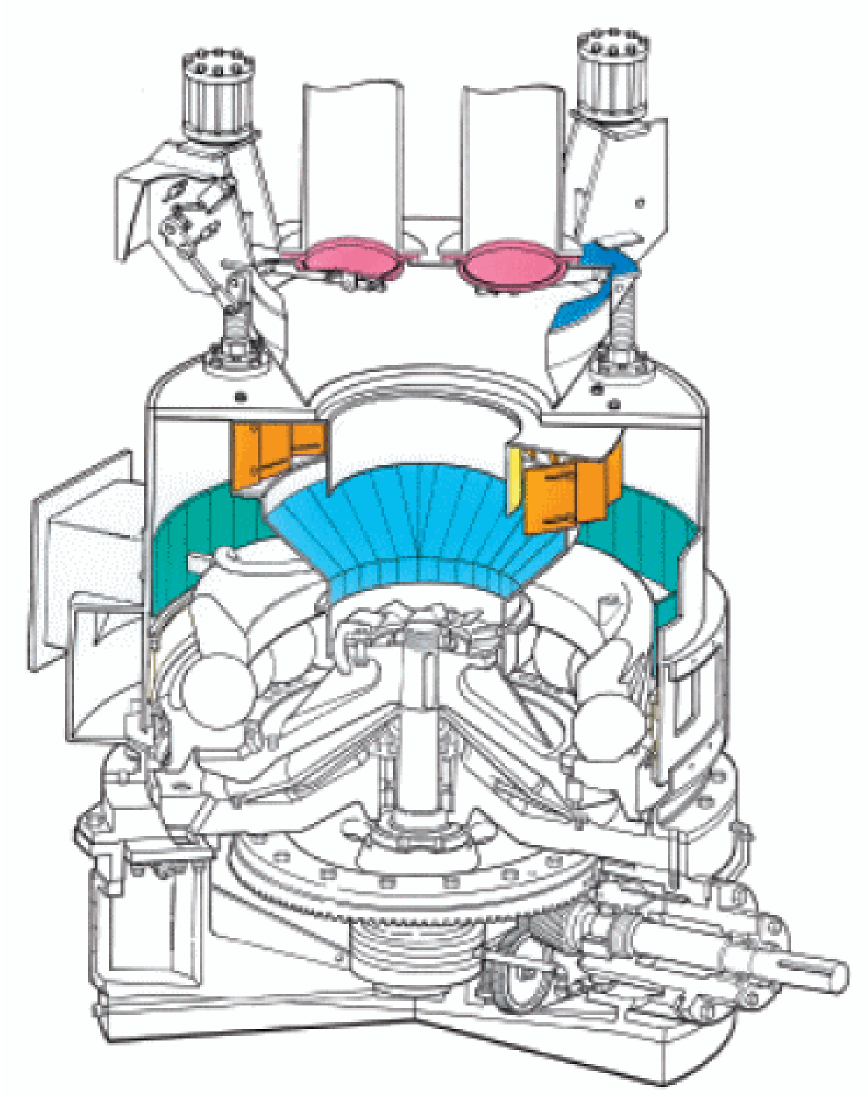
BALL TUBE MILL INSTALLATION

Impact mills consist of a series of hammers or lugs revolving at high speed in an enclosed chamber. Grinding is by impact and attrition. Air passing through the mill dries the coal and carries any fines. A means of classification is generally provided for returning oversize particles. This type is compact, low in cost, and may be built in very small sizes. It is well adapted to drying, because there is intimate mixing of air and coal. Maintenance and power consumption are relatively high, and it is difficult to maintain uniform fineness over the life of the wearing parts. The small storage capacity makes this type well adapted to quick starting and intermittent operation.



Ball and race pulverizer The ball-and-race pulverizer works on the ball-bearing principle. The grinding elements constitute the distinguishing feature. In the ball-and race pulverizer these elements consist of a row of balls with one race below them and another above. The top race is stationary and the bottom race rotates by a vertical shaft below the bottom race turned by a horizontal motor through a worm gear that reduces the speed to between 75 to 225 rpm. Raw coal is fed from above into the grinding zone. Pulverizer air causes the coal to circulate through the grinding elements where some of it is pulverized in each pass through the row of balls. This mill is almost always operated under a positive pressure. This avoids erosion of the primary air fan blades.

Steam its Generation and Use by Babcock and Wilcox 39th edition copyright 1978, page 9-6

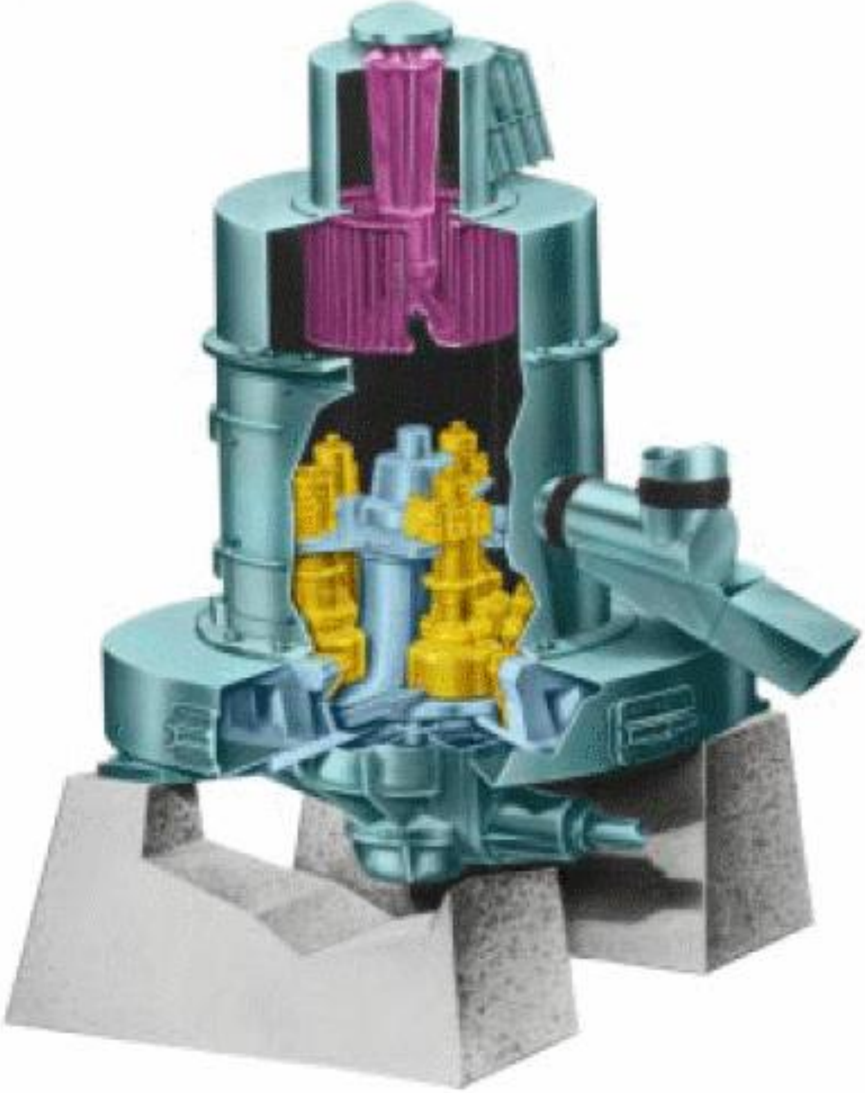


The ring roll mills pulverize by passing the coal between two surfaces, one rolling over the other. Grinding is accomplished by crushing and attrition. These types have low power consumption, are compact, maintain fineness over the life of the wearing parts, and handle wet coal with only a small reduction in capacity.

Kent's 12th page 7-85

Either four or six rolls are used. Pendulum type roll assemblies are mounted on a central spindle and free to swing outward. The rolls exert a crushing force on coal trapped between the roll and the surrounding outer ring. Any coal falling past the rolls is scooped up by rotating plows and carried back to the grinding ring

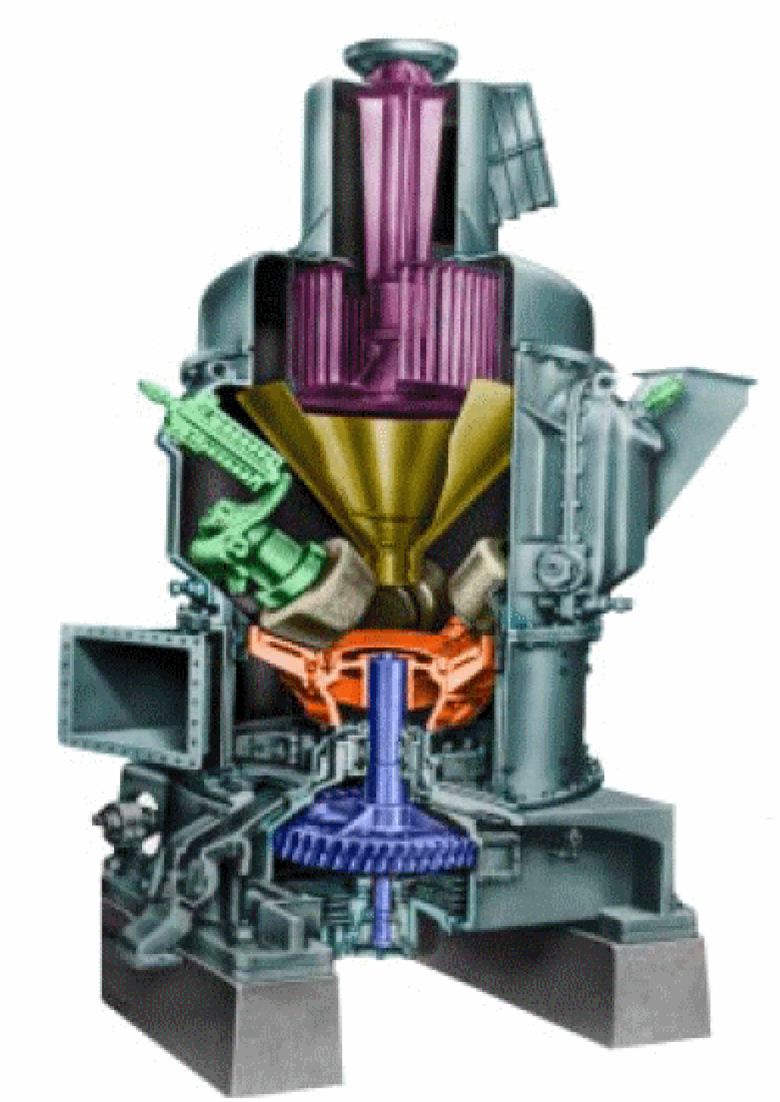
Blue Combustion Engineering page 7·19



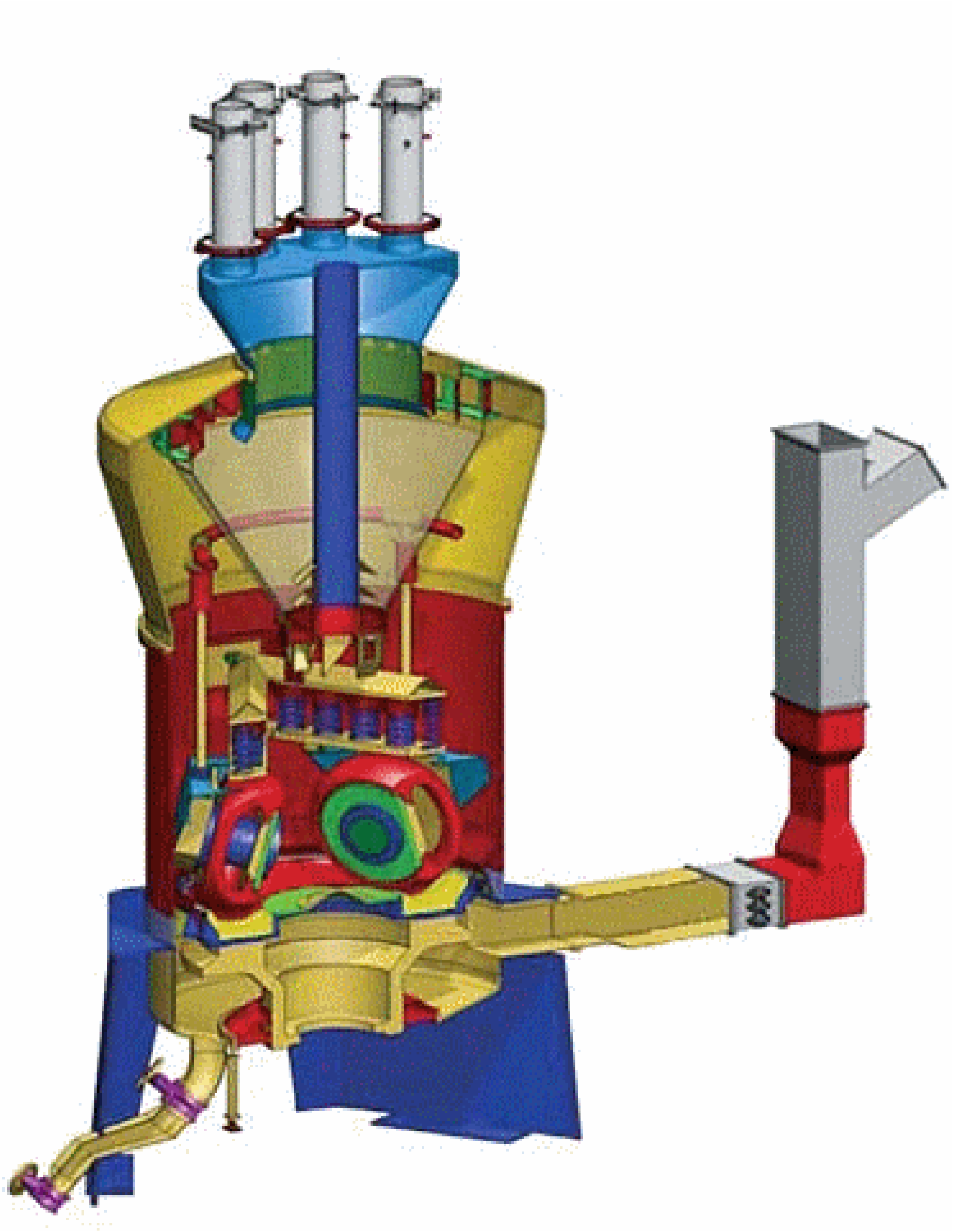
The bowl mill consists essentially of a grinding ring, carried by a revolving bowl whose rim speed is approximately 1200 ft per minute. Stationary rolls, pre-loaded by adjustable spring pressure, are set so that they do not come in contact with the ring. A classifier, whose outlet is connected to the mill exhauster, is located above the grinding chamber. The entire mill assembly is suitably enclosed in a reinforced cast-iron, or welded steel housing.

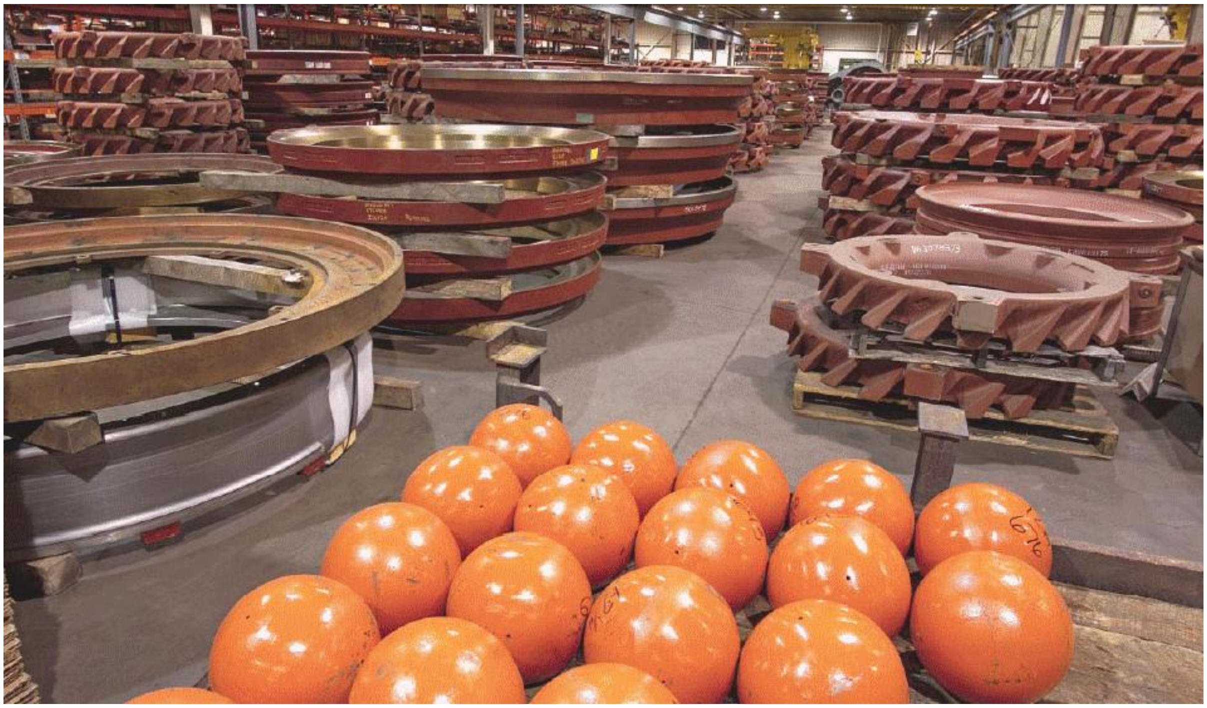
When the mill is in operation, a rotary feeder discharges coal into the spinning bowl. Because of the bowl shape, the coal is thrown by centrifugal force and tends to flow up the grinding face and over the rim. This grinding face or ring is set at an angle which retards the coal sufficiently as it passes through the grinding chamber so that it can be nipped and crushed by the rolls.

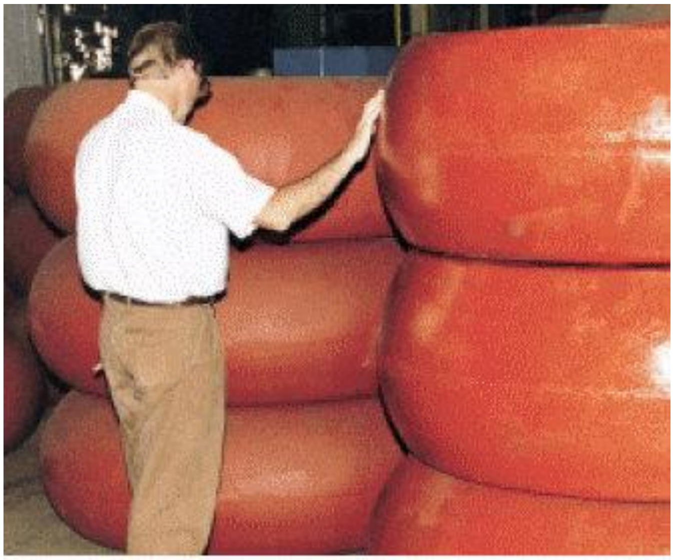
Blue Combustion Engineering page 7· 24

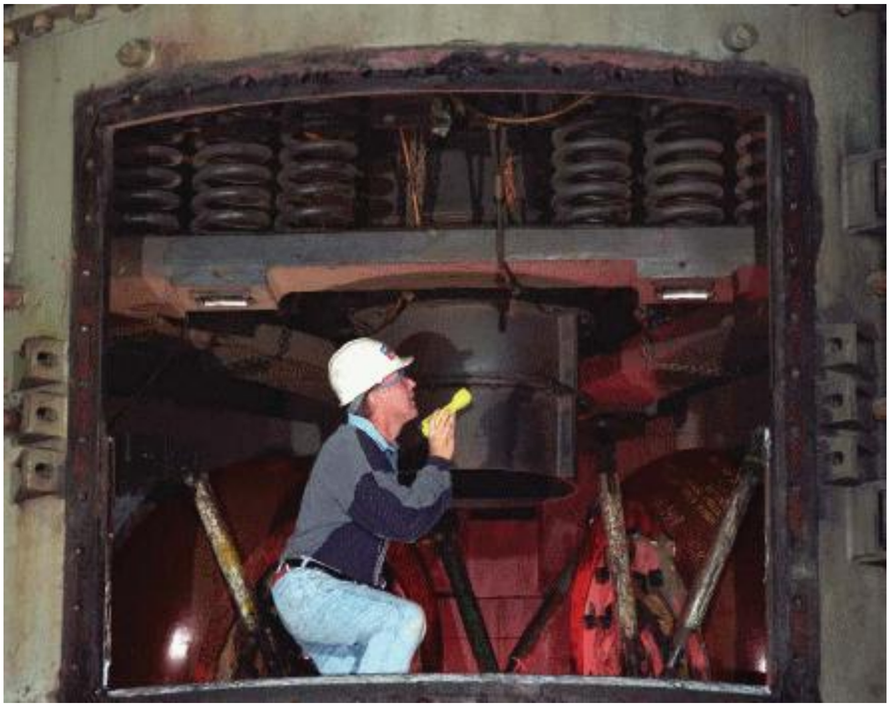


The Roll Wheel Mill Loading system allows independent radial movement of each roller; maintains design performance with up to 40% weight loss of roll wheel tires; stationary or variable speed rotating dual stage classifiers; non-integral gear drive.









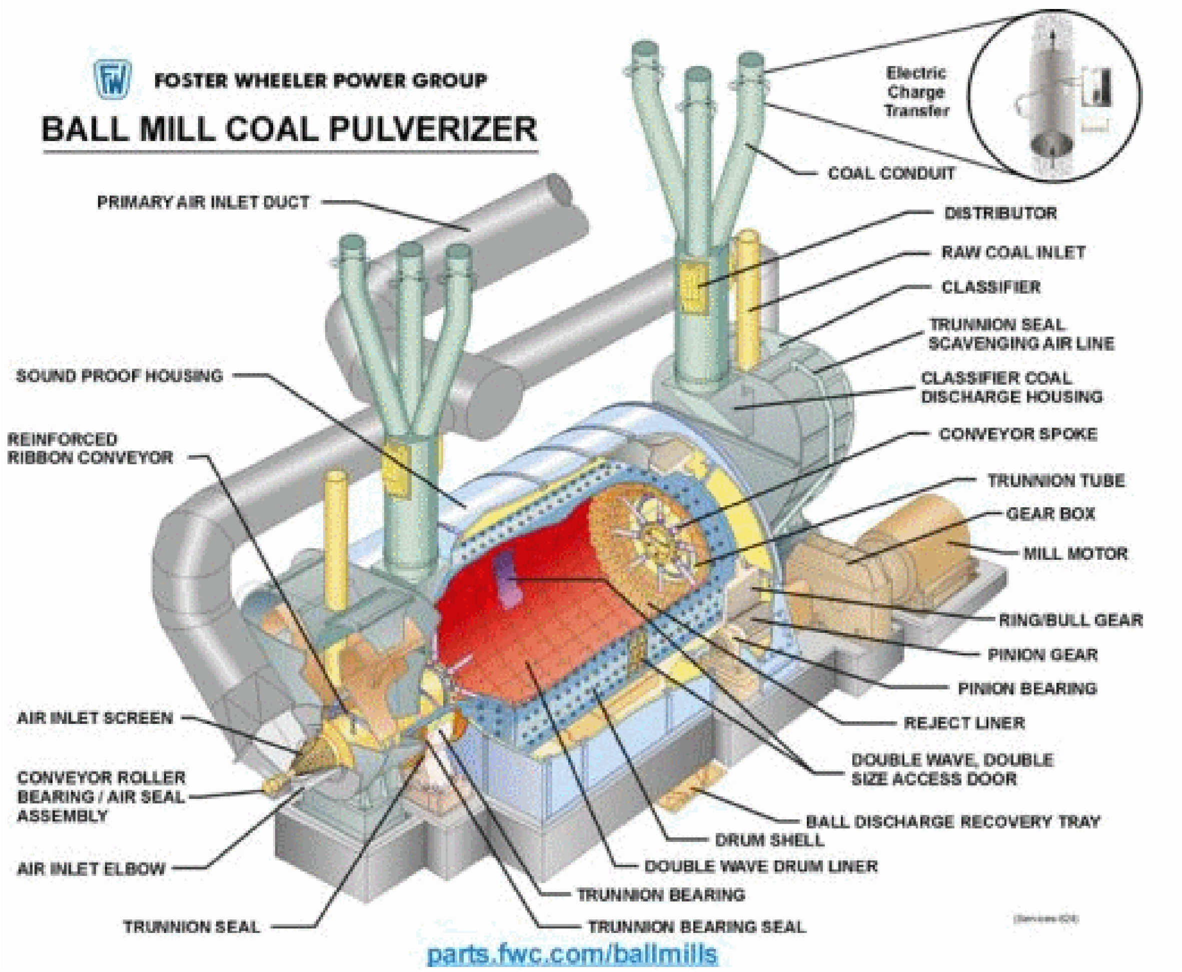
The top photo shows spare parts for the ball and race pulverizer. The middle left photo shows the spare “tires” for the roll wheel pulverizer. The middle right photo shows spare rollers for the bowl mill and the bottom photo shows an inspector checking out the B and W Roll Wheel Pulverizer. Note the springs that adjust tension on the wheels, and the round chute in the middle where the coal will drop down to be pulverized.

Ball Mills

Describe a ball mill.

Ball mills consist of a horizontally rotating cylinder less than half full of steel balls of various diameters. The speed of rotation is 20 rpm. Balls carried up the periphery in the direction of rotation continually cascade toward the center. Coal mixed with the ball charge is pulverized by impact, attrition, and crushing. Hot air passes through the mill, dries the coal and carries the fines to a classifier where the coal is either passed along to the burner or sent back to the mill for further pulverization. This mill is a low maintenance, quick response mill with high power consumption.

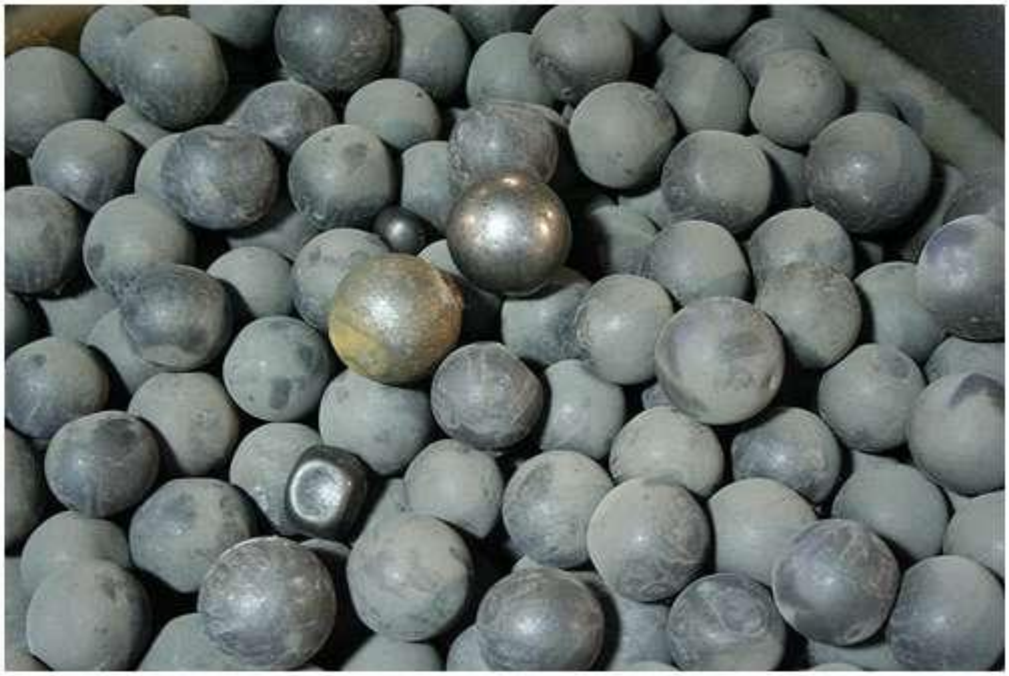
Kent’s 12th edition page 7-85



What size balls are used in a ball mill?

Ball Mills use steel or special-alloy balls, about 1 to 2 inches (25 to 50 mm) in diameter.

Honeywell Flame Safeguard Controls page 35

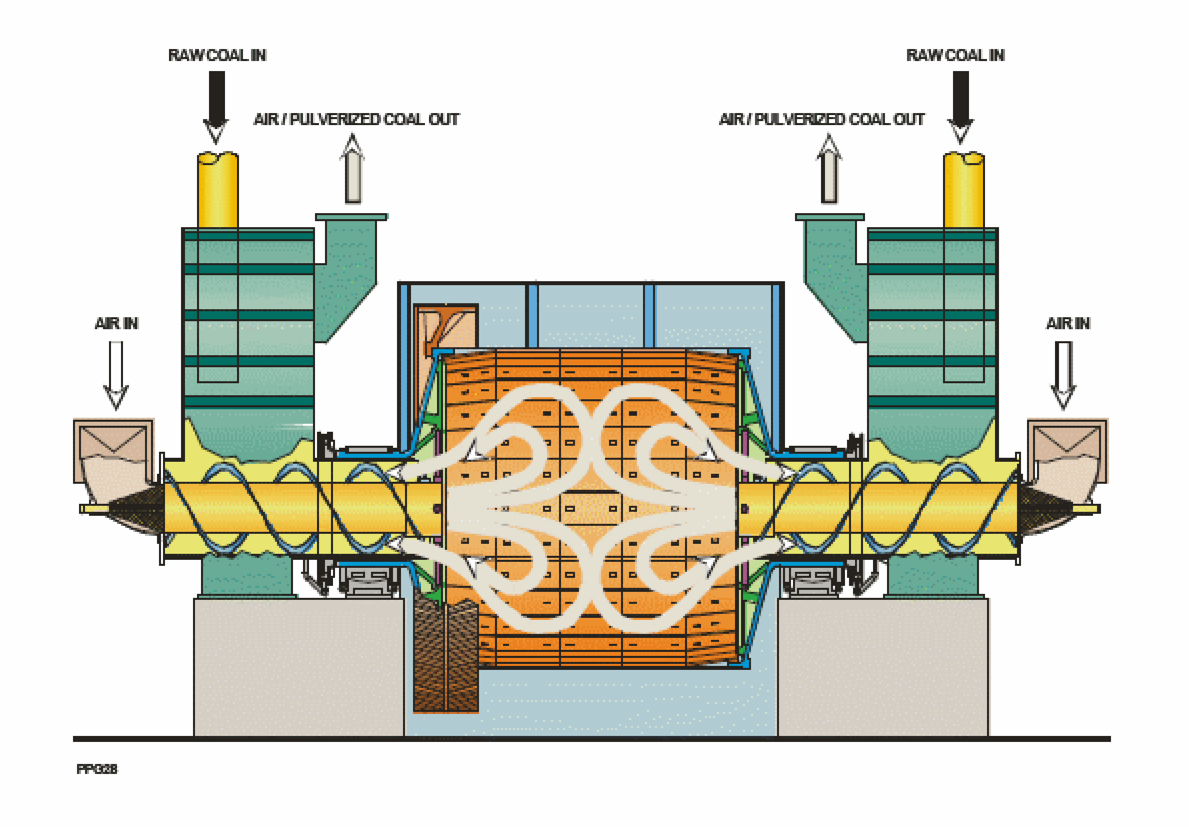


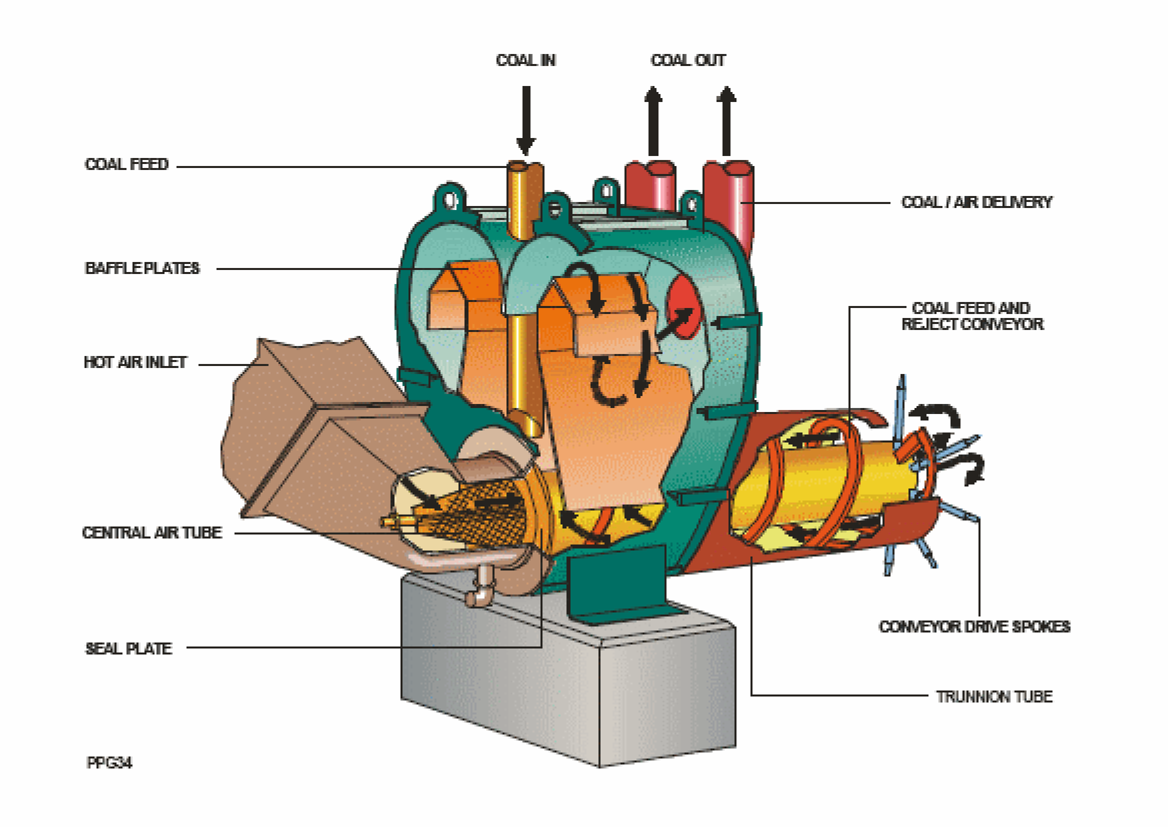
These steel balls are used to crush the coal at the Wabash River Generating station into a liquified dust that is then fed into the blast furnace to create the heat that turns river water into steam, which is then captured into turbines and made into power. The older balls are more deformed than their shiny newer round counterparts.

How fast does a ball mill revolve?

It rotates at a low rate of speed; 20-25 rpm.

Honeywell Flame Safeguard Controls page 35

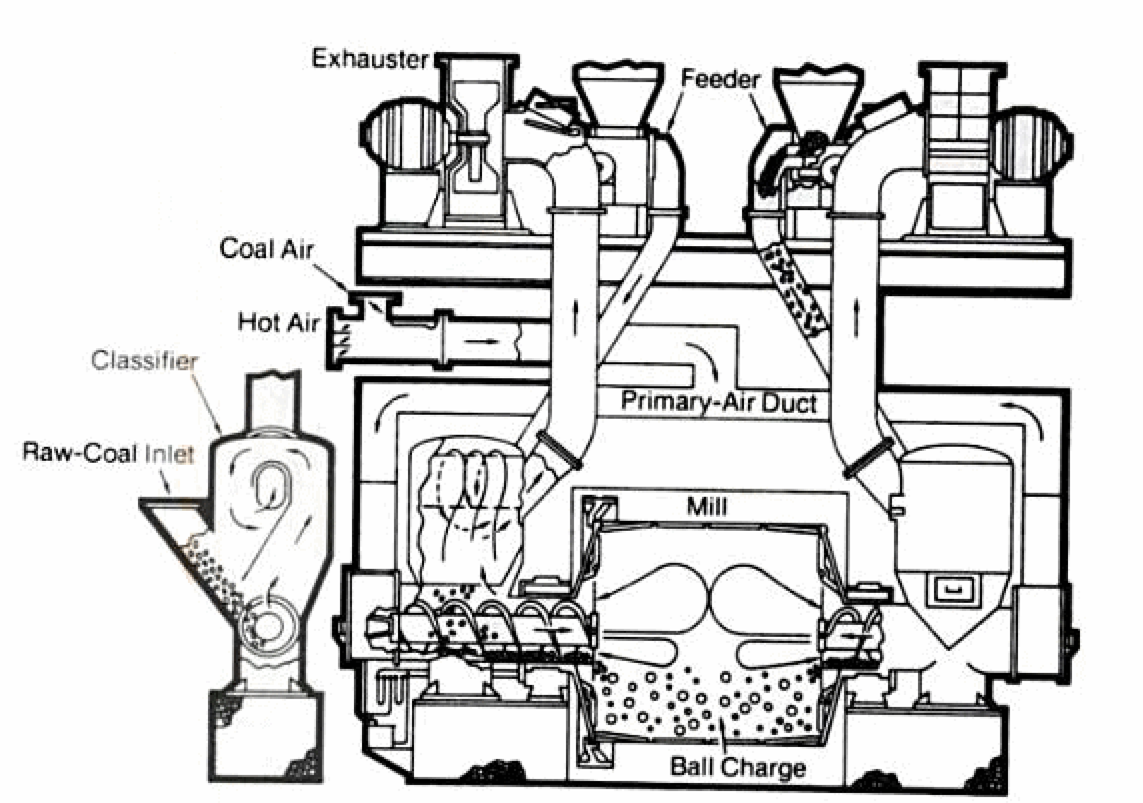


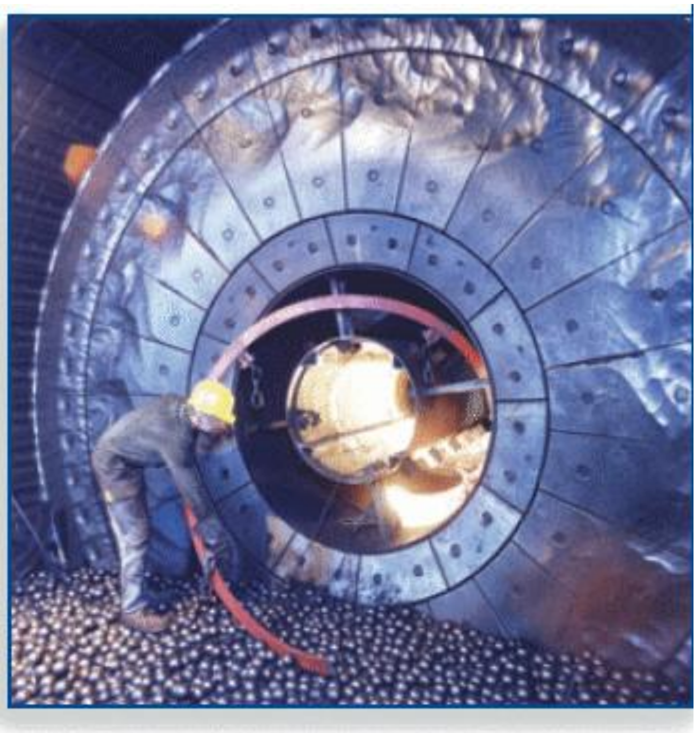


How full is a ball mill filled with balls?

The balls occupy about one-third of the drum volume.

Honeywell Flame Safeguard Controls page 35





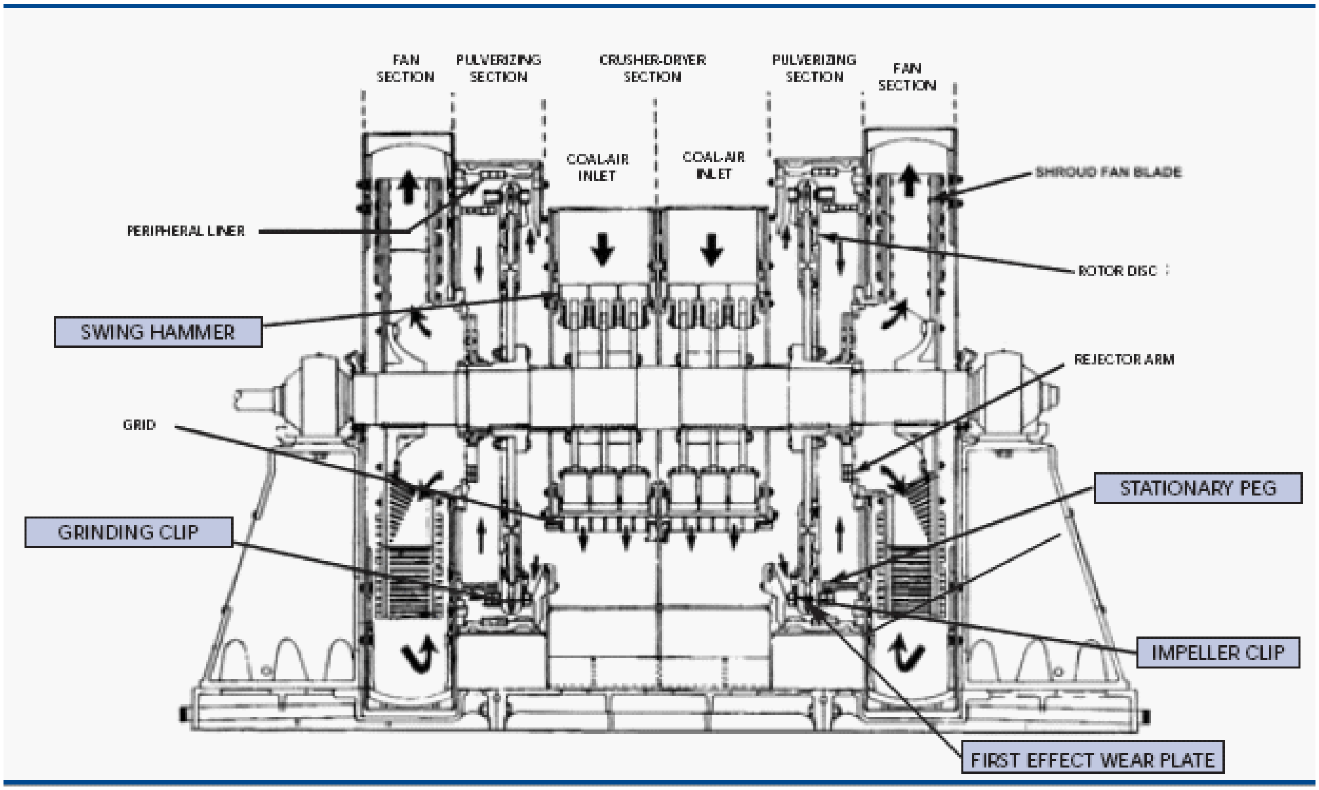
INSIDE A TYPICAL BALL TUBE MILL

Impact Mills

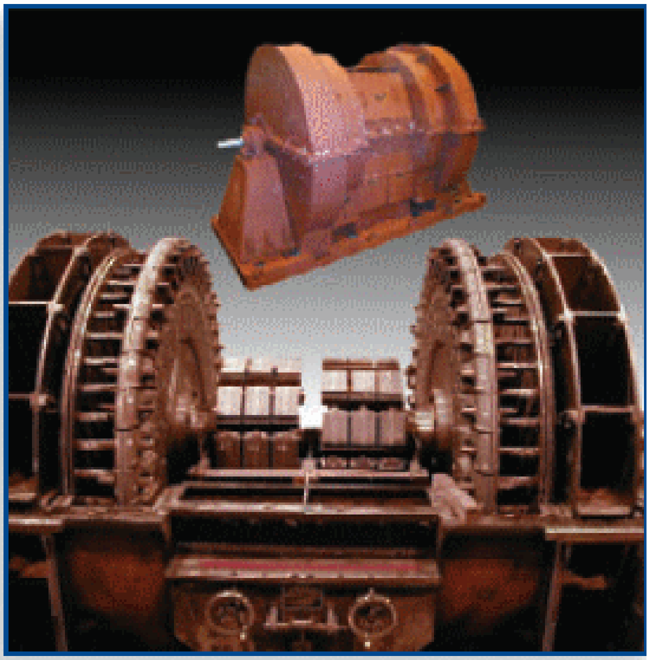
Describe an impact mill

Impact mills consist of a series of stationary hammers or lugs mounted on a revolving disk in an enclosed chamber. Grinding is accomplished by a combination of impact on the larger particles and attrition on the smaller particles. An exhauster type fan is used on these mills and either a built-in or an external type of classifier is used. These mills are excellent dryers, compact, and low cost. Maintenance and power consumption is high.

Blue Combustion Engineering page 7·2



NEW ONE PIECE HAMMER



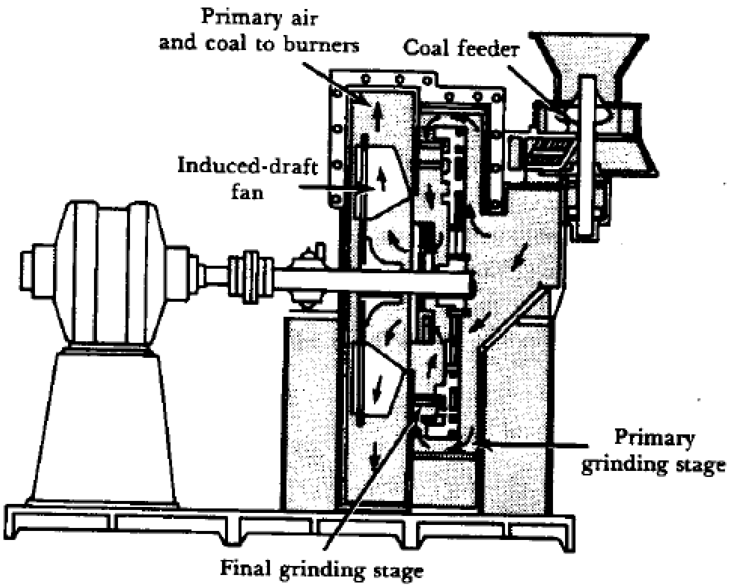
What prevents the hammers in an impact mill from hitting one another?

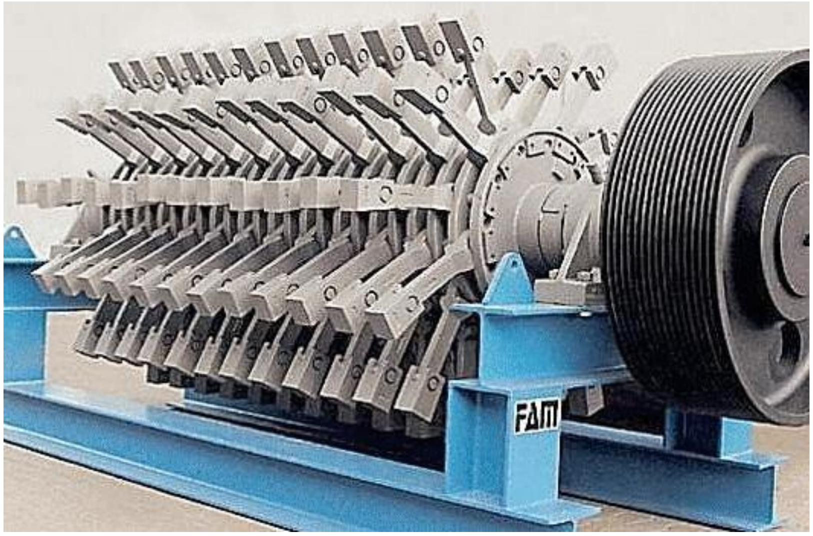
This design has no metal-to-metal contact between pulverizing elements and requires no adjustments to compensate for wear.

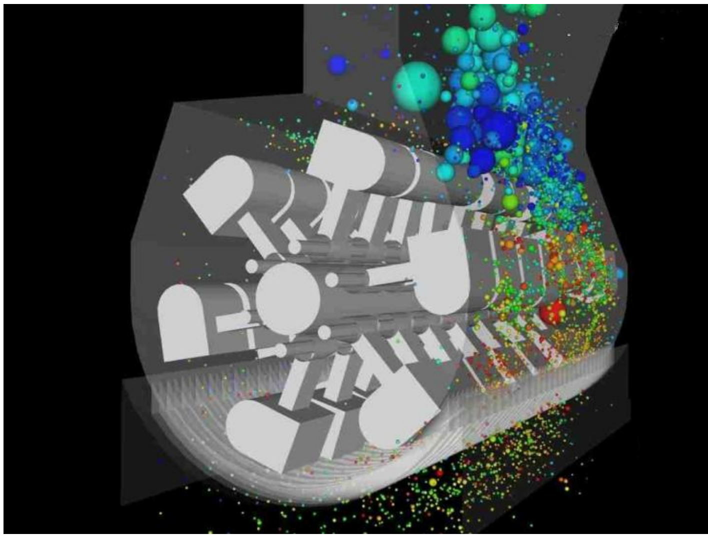
Steam Plant Operation by Woodruff and Lammers 8th edition page 285

How fast does an impact mill revolve?

It revolves at a high rate of speed; above 225 rpm.



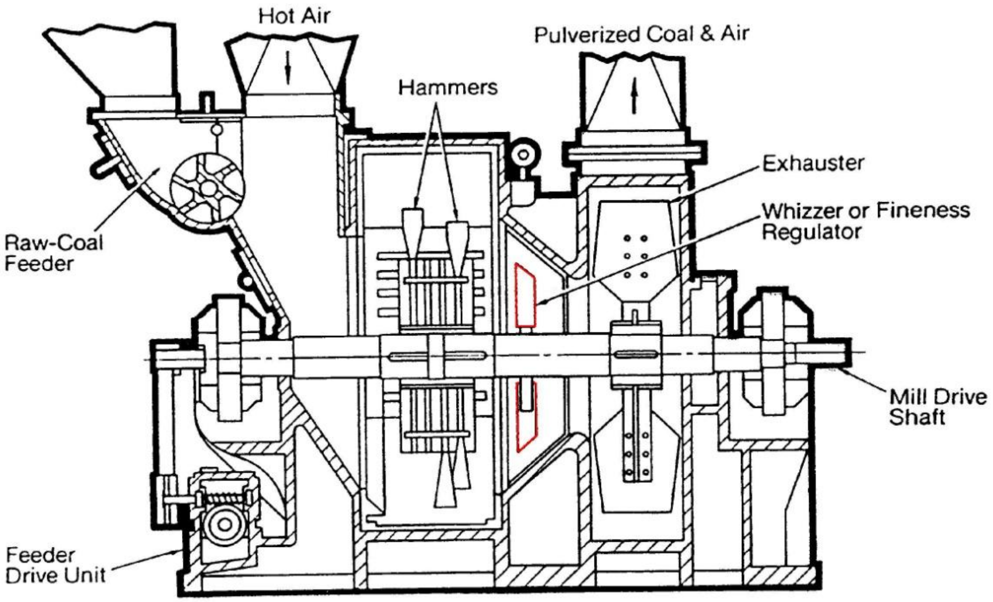


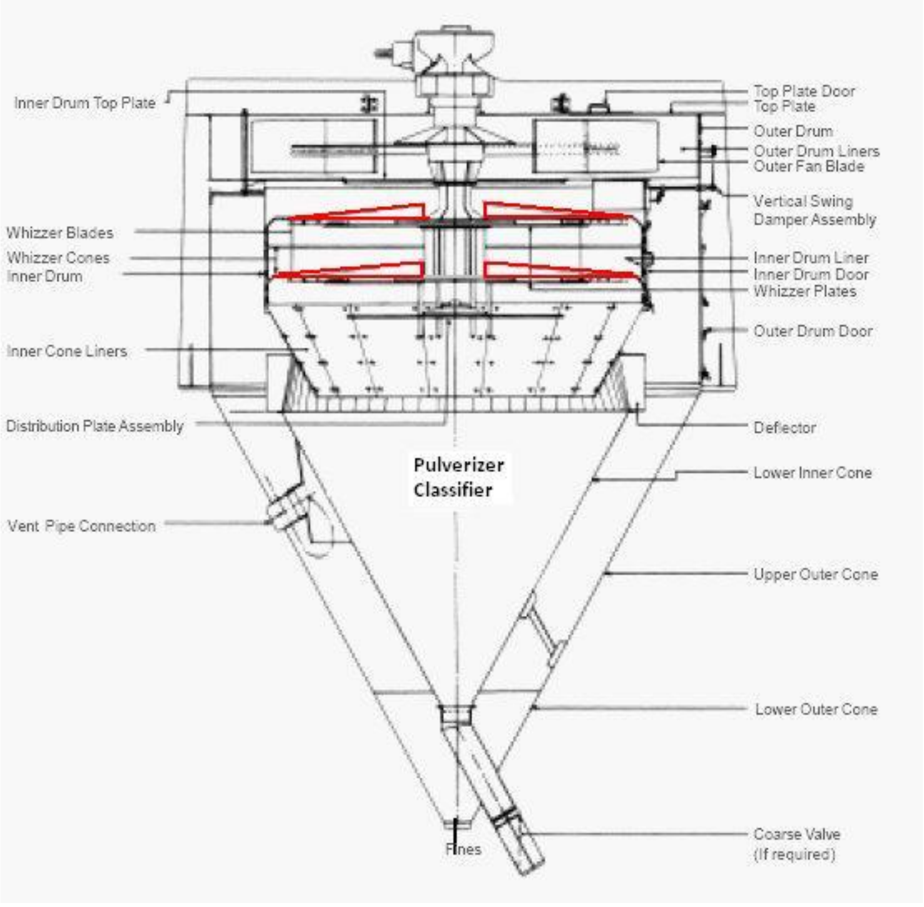


What is a "whizzer"?

The exhauster is a ruggedly built steel-plate fan designed for handling abrasive materials. A semi-shrouded fan wheel with so called "whizzer" blades handles the coarser coal particles. It is also used in some Bowl Mill style pulverizers

Honeywell Flame Safeguard Controls page 35



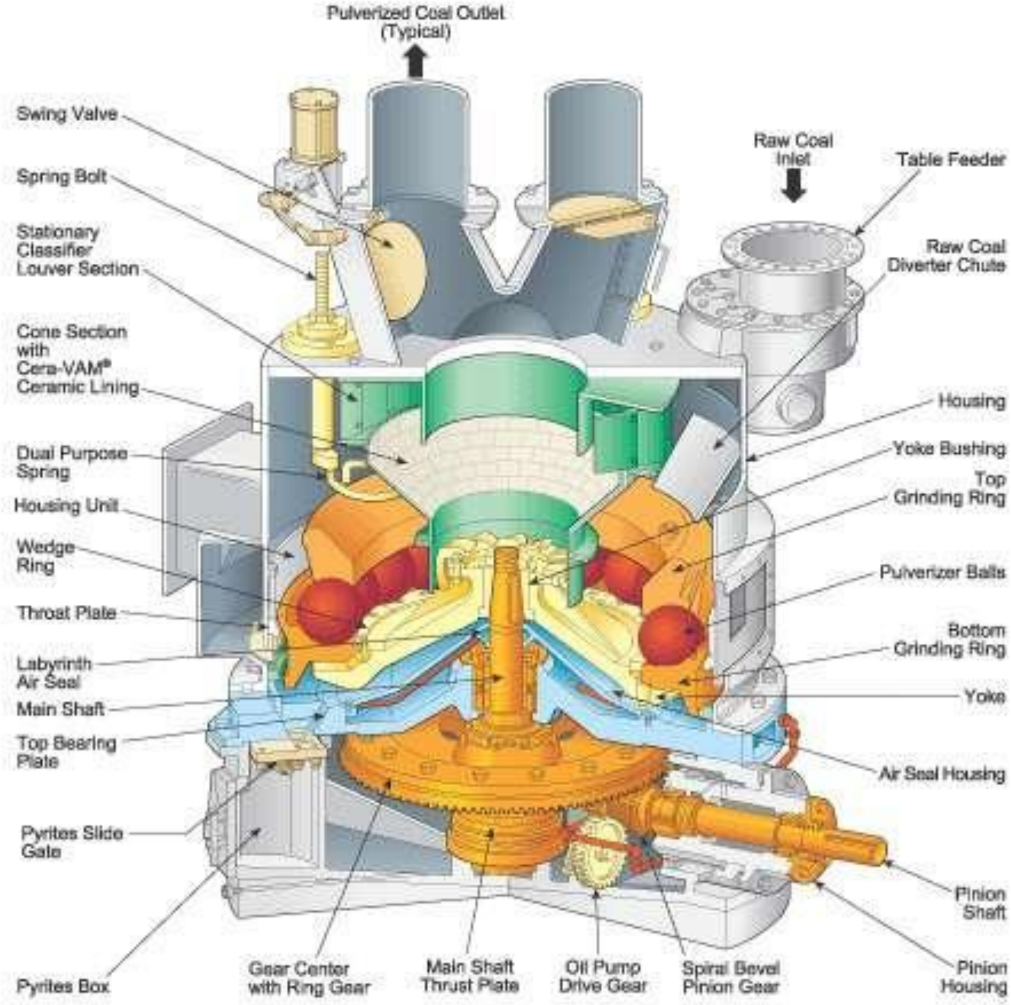


Ball and Race Mills

Describe a ball race mill.

The grinding element consists of a service of balls set between a pair of raceways. The lower raceway and the bowl shaped yoke are rotated by a drive motor outside the pulverizer casing. The upper raceway is stationary and held in place by adjustable springs. A classifier is mounted just inside the pulverizer outlet. A wind box encircles the mill. On large mills there are two sets of balls and races, one above the other. This mill uses a primary air fan, thus the mill is in a positive pressure in relation to atmospheric.

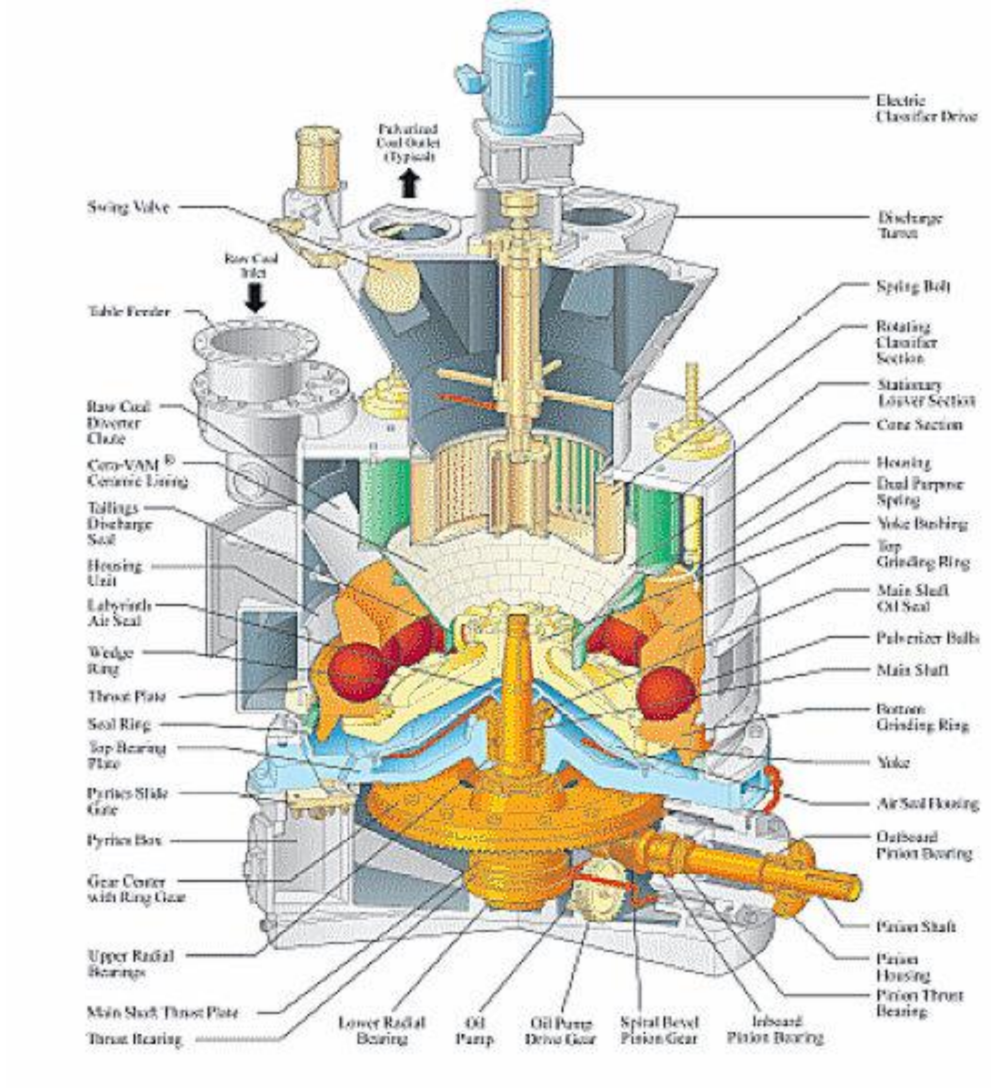
Detroit Edison Steam Course "Fuel Burning Equipment" page 31 and 33

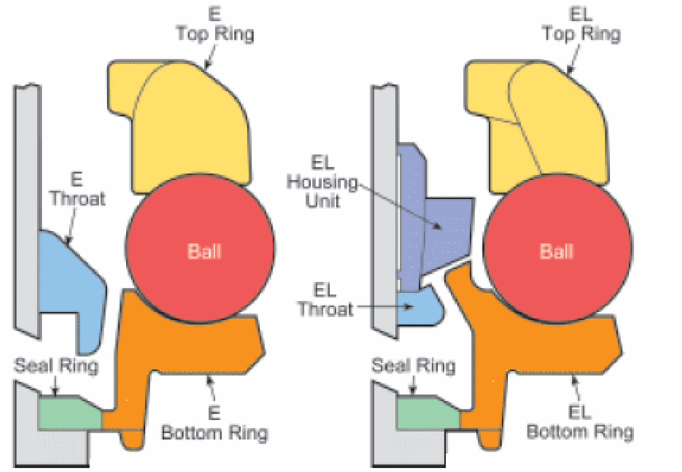


How fast does a ball and race mill revolve?

It is a medium speed mill and operates at 75-225 rpm.

Honeywell Flame Safeguard Controls page 35





What is the average life of a ball in a ball and race mill?

The average life of a ball is two years.

Honeywell Flame Safeguard Controls page 36

Is a Babcock & Wilcox ball and race mill operated under vacuum or pressure?

This mill is designed for pressurized operation. Raw coal is fed into the grinding zone to mix with partially ground coal. Primary air causes the coal to circulate through the grinding elements, where some of it is pulverized in each pass between the rings and balls. As the coal becomes fine enough to be picked up by the air, it is carried to the classifier. Oversize coal is removed and returned to the pulverizer.

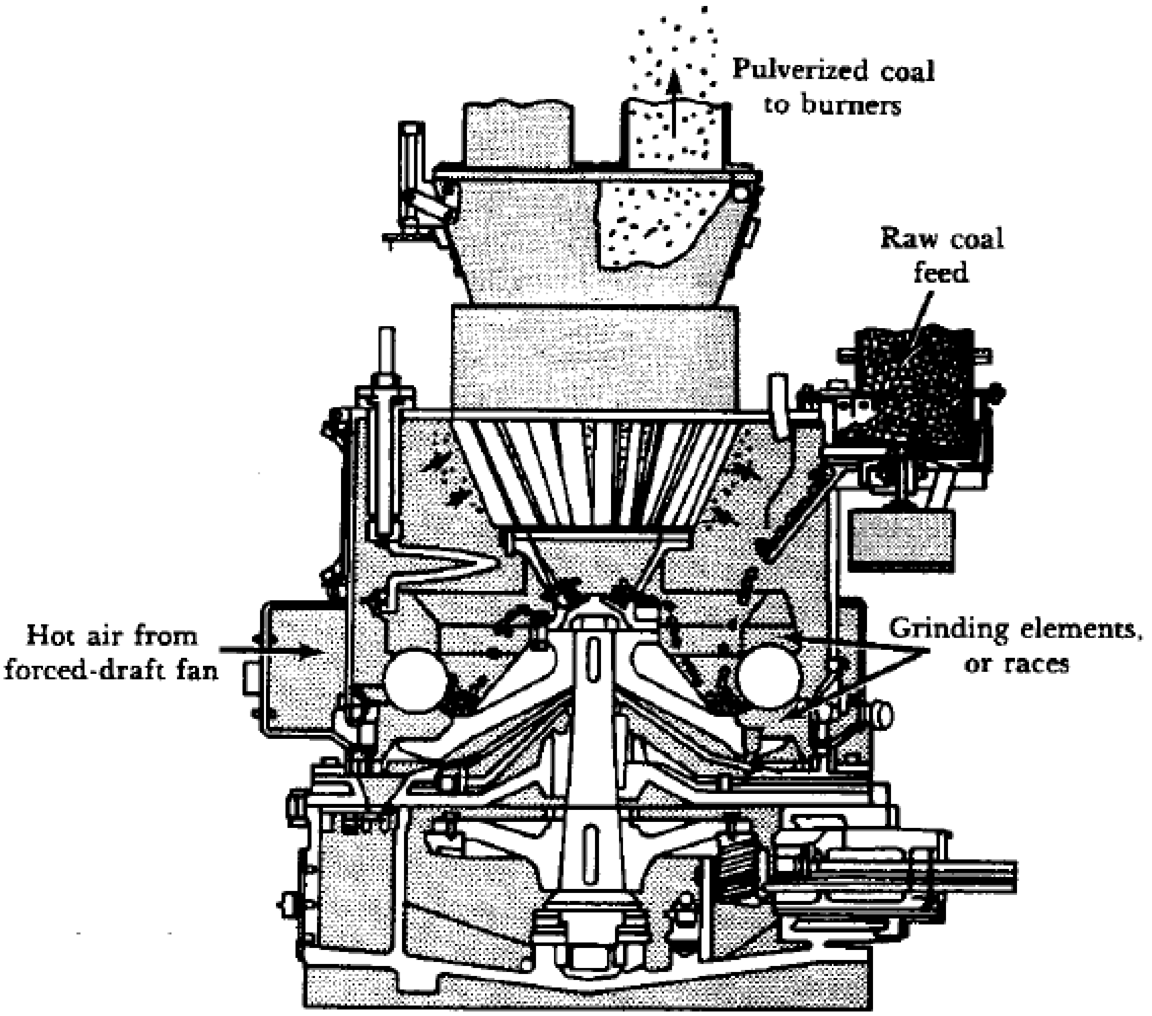
Honeywell Flame Safeguard Controls page 36

What type of fan does a ball race mill use?

The primary air fan forces the air through the pulverizer and, therefore, handles clean air, but the pulverizer is under pressure. Leakage through the mill casing causes the pulverized fuel to be blown out into the boiler room.

Primary air fans force air through the mill. Exhauster fans draw air through the mill.

Steam Plant Operation by Woodruff and Lammers 3rd. edition page 168


Pulverized coal to burners
Raw coal feed
Hot air from forced-draft fan
Grinding elements, or races

Are all ball race mills positive pressure?

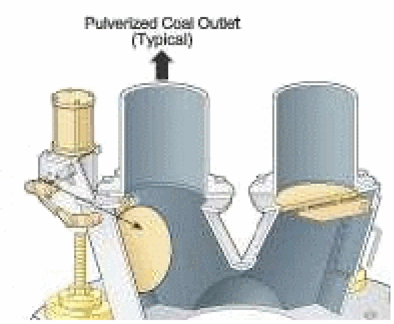
Ball and race mills may be operated either under pressure or vacuum. In the pressurized mill a primary air fan is placed in the primary air duct before the mill and forces the air through the mill. In the case of a ball and race mill operating under a vacuum, the exhauster draws the primary air through the mill.

Detroit Edison Steam Course Fuel Burning Equipment page 33

What purpose does the damper on the discharge side of a ball race mill serve?

During start-up of a pulverizer, primary air pressure and furnace pressure is very critical. In order to maintain proper primary air pressure during start-up, the discharge air damper is adjusted usually it is about 50% open. If one mill serves two burners, then two dampers may be placed in the discharge plenum, one to each burner, to balance fuel flow and pressure. With mills using exhauster type fans the damper is in the inlet piping to the fan.

Blue Combustion Engineering page 30·21



How do you know when a Babcock and Wilcox ball race coal mill is empty?

The mill will start to get very noisy. The amp draw will decrease on the meter. The draft gauges will change.

Operator - Mistersky Power Plant

On a ball race mill, what indication would an operator have of loaded or unloaded condition?

An amperage meter located either at the mill drive motor or in a remote location would give the operator an indication of a loaded or unloaded condition. High amperage draw would indicate a loaded condition and low amperage would indicate an unloaded condition.

George Brown, Mistersky Powerplant

What type of coal does a ball race mill use?

The ball race mill can pulverize any type of coal except in slurry form. These types have low power consumption, are compact, maintain fineness over the life of the wearing parts, and handle wet coal with only a small reduction in capacity.

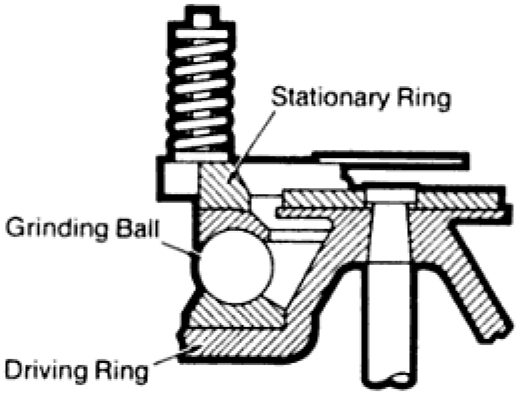
Kent's 12th edition page 7-85

All pulverizers utilize a cheap, low grade of fuel. The coal must be crushed before entering the pulverizer so that all particles pass through a 3/4" screen and tramp iron and foreign matter must be removed. The grindability of a particular coal will determine mill capacity and cost per pound to pulverize. Pulverized anthracite is very rare.

Can a Babcock and Wilcox ball and race mill be adjusted?

This mill uses steel balls and rings or races as grinding elements. The lower race is power driven but the upper is stationary. Pressure is exerted upon the upper race by means of springs. The force exerted by these springs can be adjusted by screws which extend through the top of the mill casing. The spring tension must be adjusted to compensate for wear of balls and races. This adjustment is made by means of the bolts which extend through the top of the mill. These bolts are adjusted to maintain a specified spring length. Once arranged to give the correct fineness the classifier does not require further adjustment.

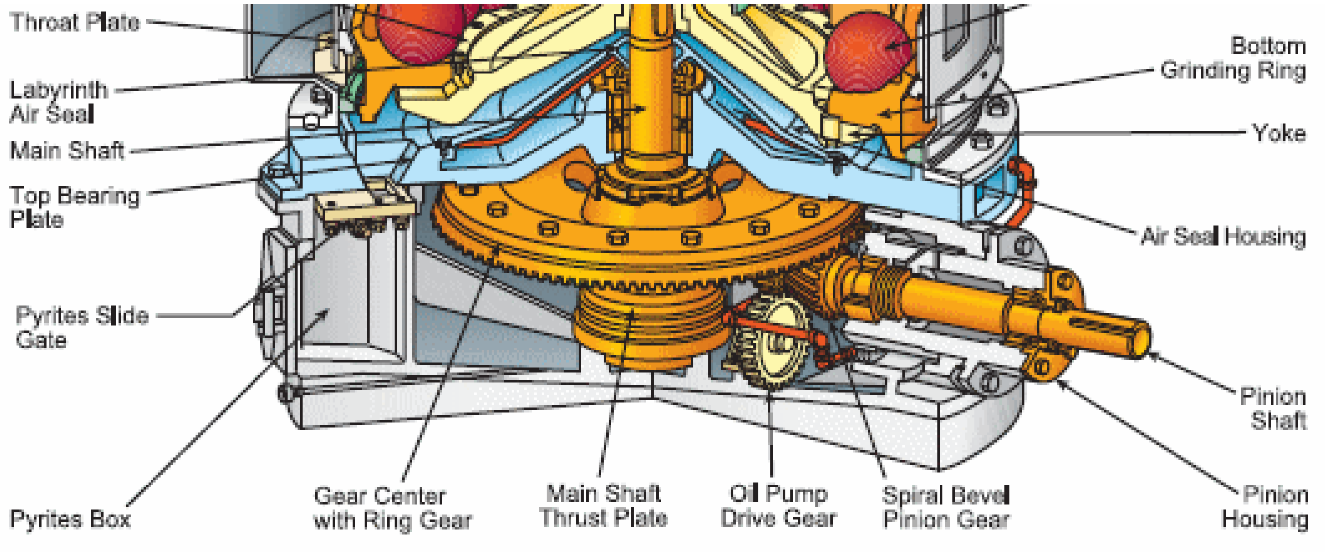
Steam Plant Operation by Woodruff and Lammers 5th edition pages 163 and 178



What is the seal air on a Babcock and Wilcox ball and race mill coal mill for?

To protect the bearings from pulverized fuel contamination, due to the fact that the mill is pressurized.

Operator - Mistersky Power Plant

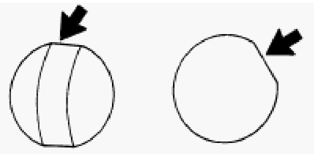


Explain the process of removing pyrites from a Babcock and Wilcox Ball and Race mill.

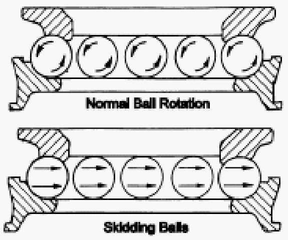
Tramp iron and hard grinding foreign material drop to the lower part of the mill housing and is accumulated in a cleanout chute. Since the mill is under a positive pressure, a inner door in the cleanout chute is ratcheted closed, so that you can open the outer door and remove the foreign material without blowing pulverized coal throughout the plant (which happened at Mistersky when an apprentice failed to close the inner door first).

Operator – Mistersky Power Plant

The balls in the ball and race mill were so worn at Mistersky, operators would throw bricks between the balls and race on startup so that as the balls crushed the bricks, enough traction was developed to start the balls turning in the race.



Grinding Ball Banding and Flat Spotting

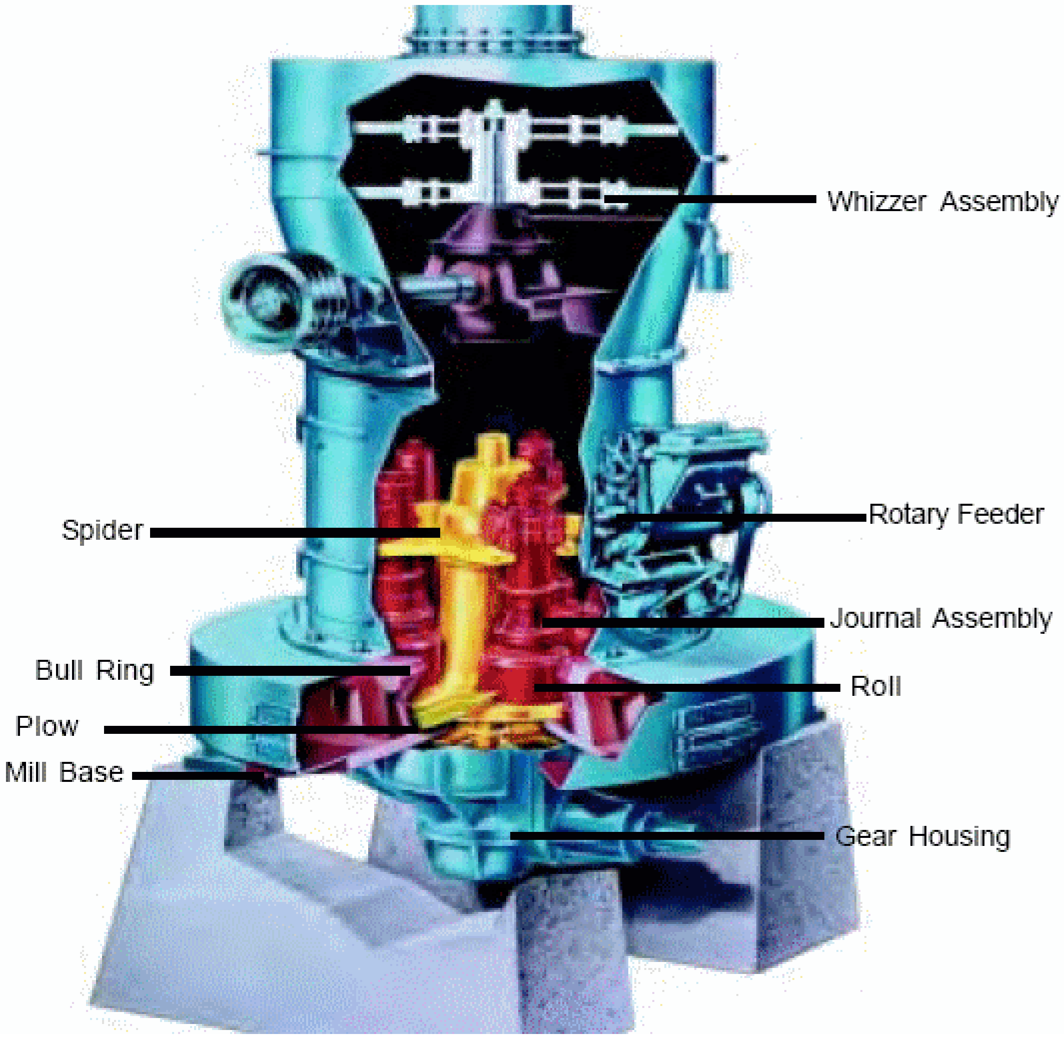


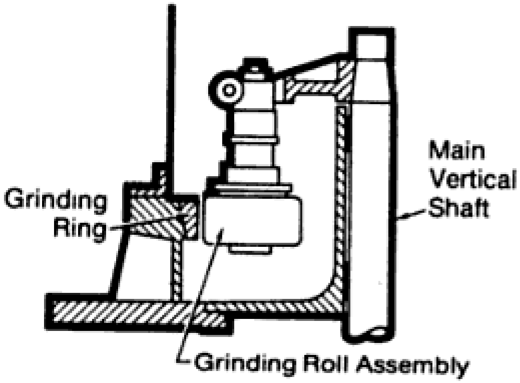
Normal Ball rotation and during skidding.

Ring Roll or Roll and Race Mills

How fast does a roll and race mill revolve?

This mill is a slow machine operating at 20-75 rpm. Honeywell Flame Safeguard Controls page 35



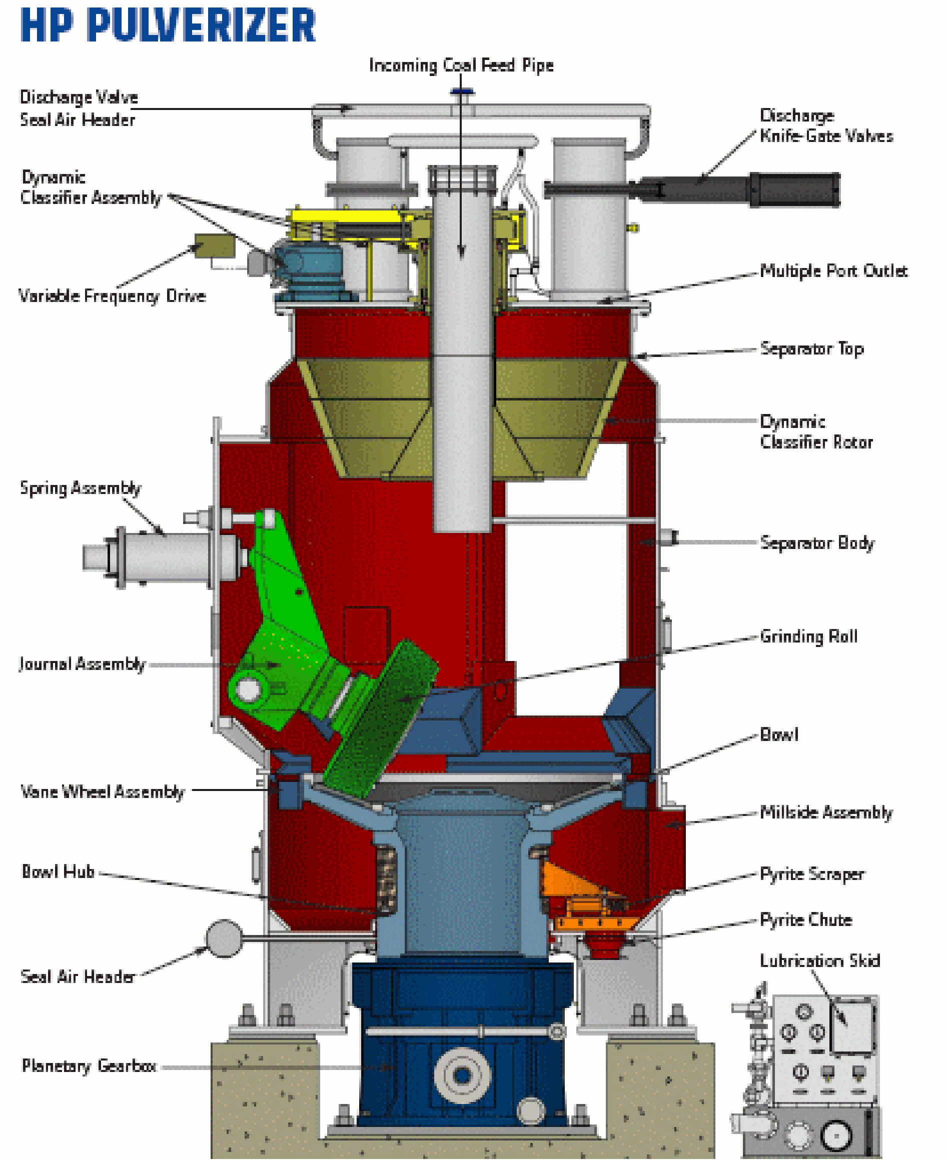


Bowl Mills

Describe a bowl mill.

The "Raymond Bowl Mill" consists of three stationary spring loaded rolls set just inside of a rotating bowl with a grinding ring affixed to the inside upper edge of the bowl. The rolls are prevented from coming in contact with the grinding ring by use of adjustable travel limit bars. As the bowl rotates (1200 ft/min) the coal is fed to the center of the bowl and thrown by centrifugal force to the outer edge of the bowl. Here it passes between the grinding ring and rotating roll, picked up by the air stream passing up past the lip of the bowl and on to a centrifugal type classifier. This mill uses an exhauster type air fan and an external motor drive.

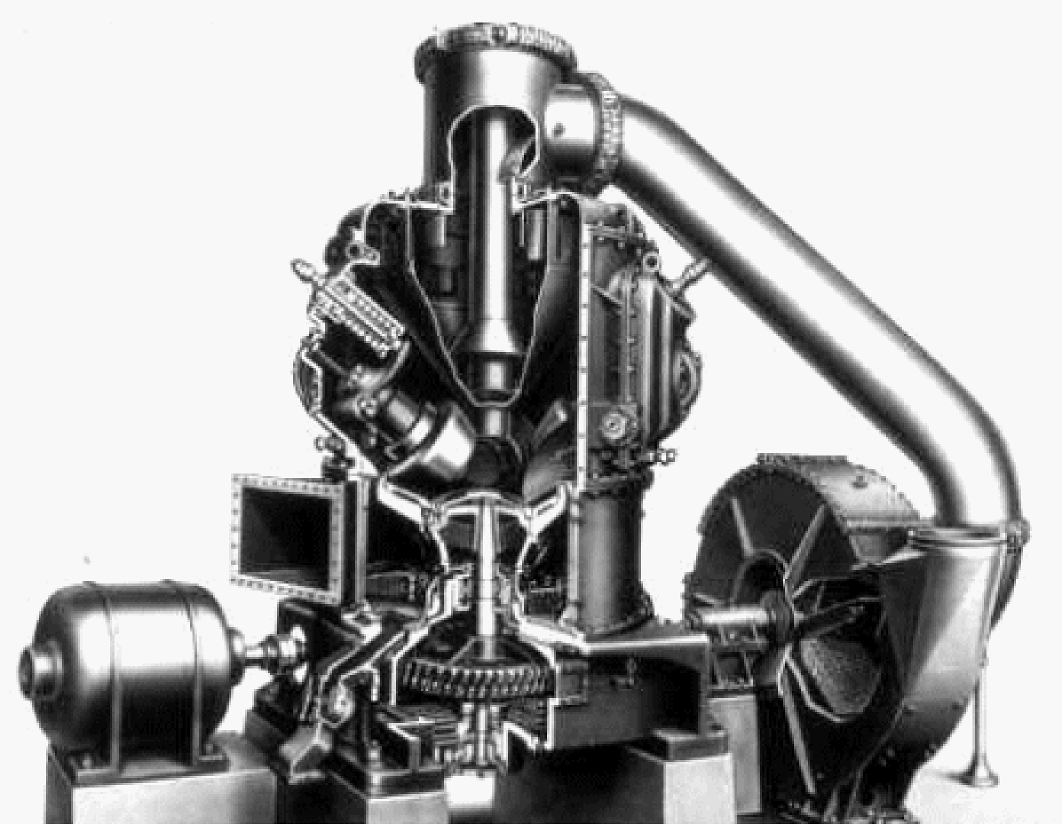
Kent's 12th edition page 7-85



Is a Raymond bowl mill operated under vacuum or pressure?

The bowl mill is usually a suction machine. An exhauster keeps the bowl under a slight negative pressure to draw in the raw coal and convey pulverized coal to the burners. As the bowl rotates at a constant speed, coal is drawn into it and ground between the rollers and grinding bowl.

Honeywell Flame Safeguard Controls page 35



How fast does a bowl mill revolve?

It is a medium speed mill and operates at 75-225 rpm.

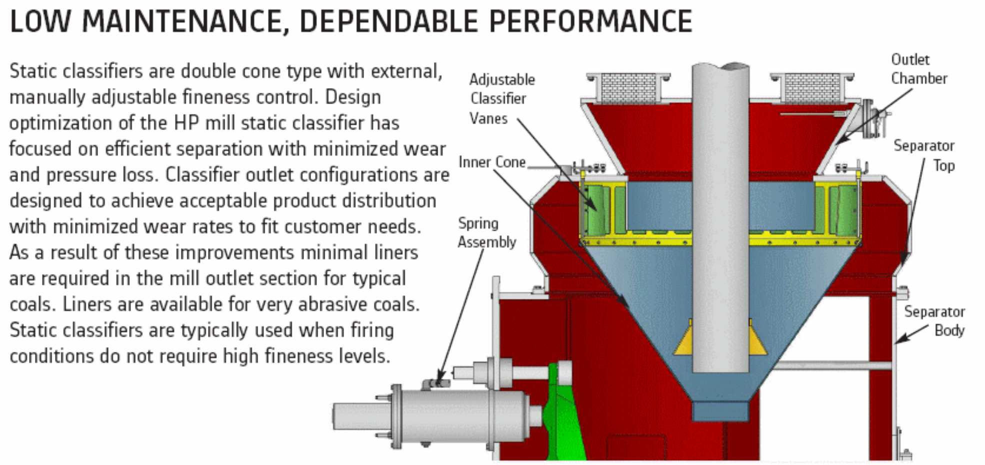
Honeywell Flame Safeguard Controls page 35

Loesche German Raymond Style Pulverizer showing pulverized coal

With a "Raymond Bowl Mill" how do you adjust it, if your coal is not fine enough?

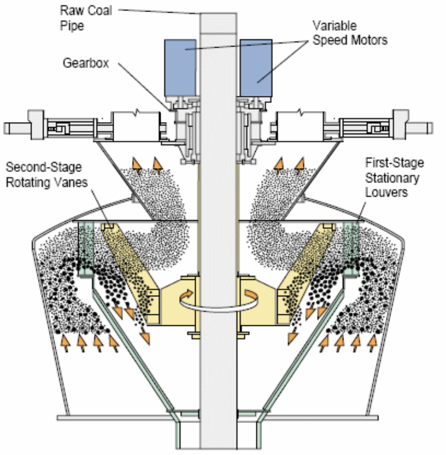
Fineness of coal at the classifier outlet is regulated by the position of the adjustable deflector vanes, where a spinning action is imported to the coal and air mixture. The degree of spin determines the sizing of the finished product.

Blue Combustion Engineering pages 7·25 and 7·26
Mistersky Operating Manual



LOW MAINTENANCE, DEPENDABLE PERFORMANCE

Static classifiers are double cone type with external, manually adjustable fineness control. Design optimization of the HP mill static classifier has focused on efficient separation with minimized wear and pressure loss. Classifier outlet configurations are designed to achieve acceptable product distribution with minimized wear rates to fit customer needs. As a result of these improvements minimal liners are required in the mill outlet section for typical coals. Liners are available for very abrasive coals. Static classifiers are typically used when firing conditions do not require high fineness levels.

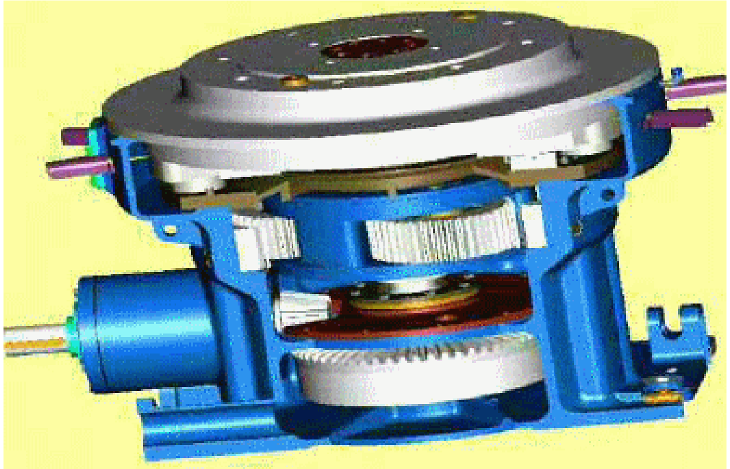


Babcock and Wilcox style classifier

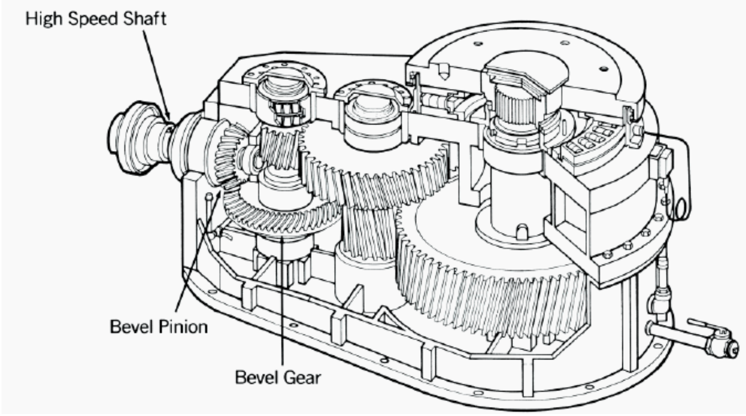
With a "Raymond Bowl Mill" what type of gear is used to drive it?

All bowl mills are equipped with a worm-gear drive. It is quiet in operation. It can be designed for a large single reduction, thereby permitting use of a high speed motor on a slow speed mill. An extension of the horizontal drive shaft extends through the gear housing. This may be used to drive the mill exhauster. By using a single motor for driving both mill and exhauster, it is possible to design a very compact unit.

Blue Combustion Engineering page 7·26



PLANETARY GEAR DRIVE



If you got tramp iron into a "Raymond Bowl Mill" how would you remove it and can it be removed while on line?

Any tramp iron or hard grinding foreign material in the feed is carried over the top of the bowl where it drops out through the air steam to the lower part of the mill housing where pivoted scrapers, attached to the bowl hub, sweep it around to the tramp iron discharge spout.

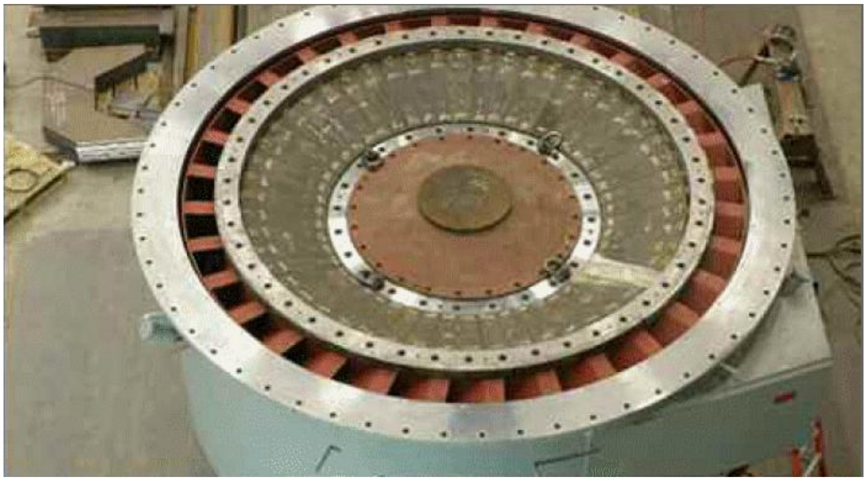
When tramp iron overcomes the weight of the weighted handle on the discharge spout, it opens.

Coal being discharged out of the tramp iron spout is usually an indication of overfeeding, although too low a spring pressure, too low an air flow, excessively worn parts, or improper adjustment will also cause coal to be discharged.

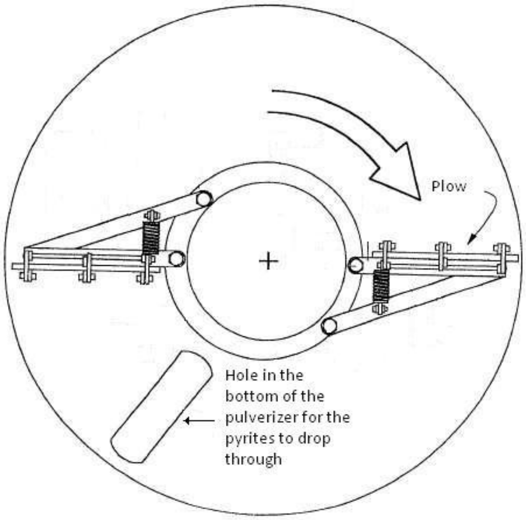
Mistersky - Operation Manual

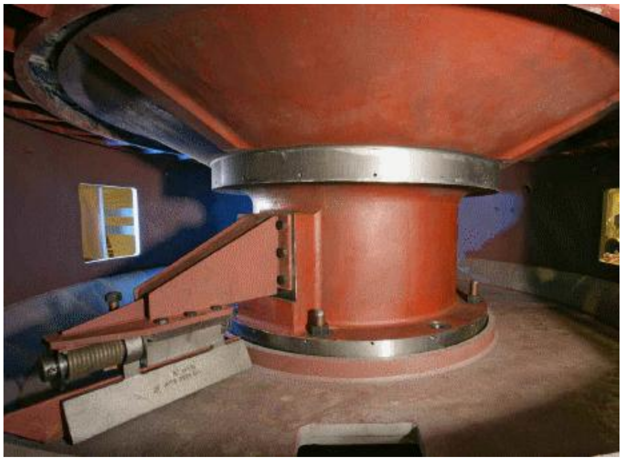
Explain the process of removing pyrites from a Raymond Bowl Mill.

Raymond Bowl Mill Any tramp iron or hard grinding foreign material in the feed is carried over the top of the bowl, where it drops out through the air stream to the lower part of the mill housing where pivoted scrapers, sweep it around to the weighed tramp iron discharge spout and is discharged automatically.



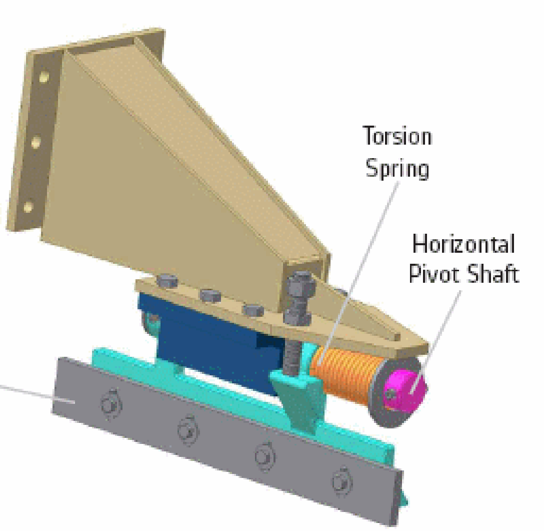
Holes for the air to pass up into the bowl area as the pyrites fall down into the plow area


Plow
Hole in the bottom of the pulverizer for the pyrites to drop through



Pyrite Plow

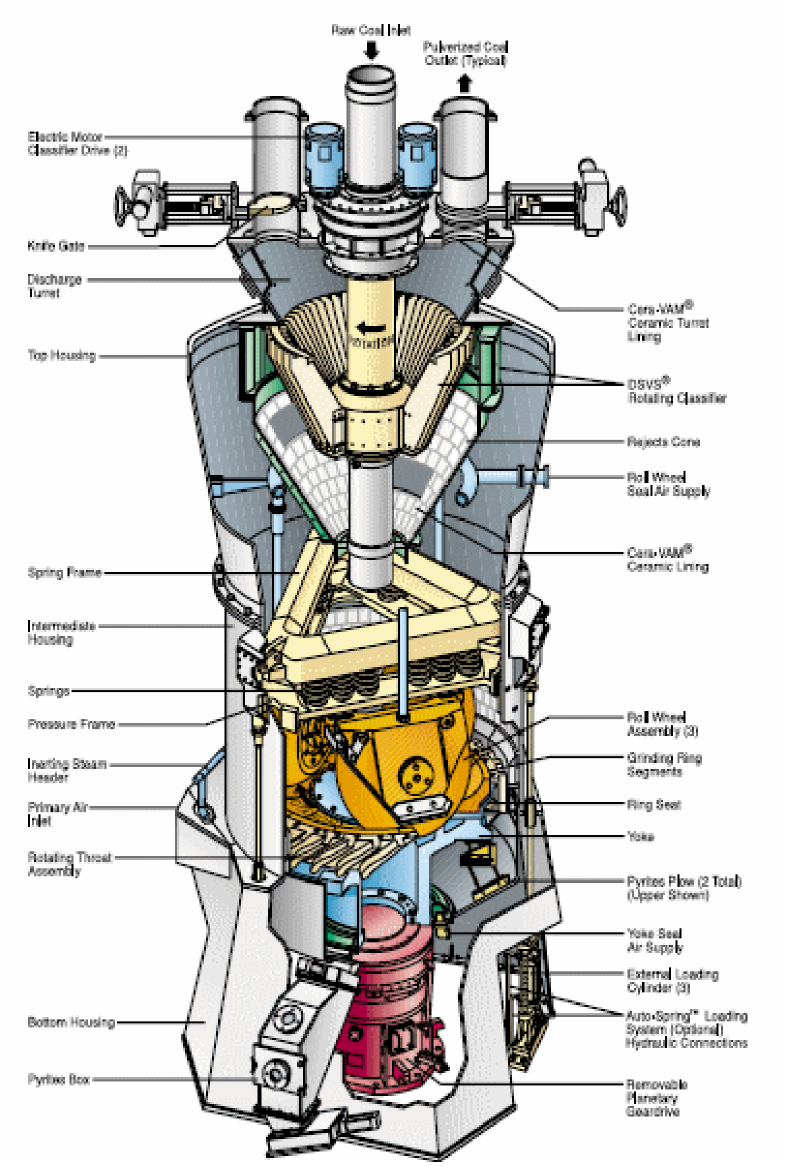
Iron pyrites ore

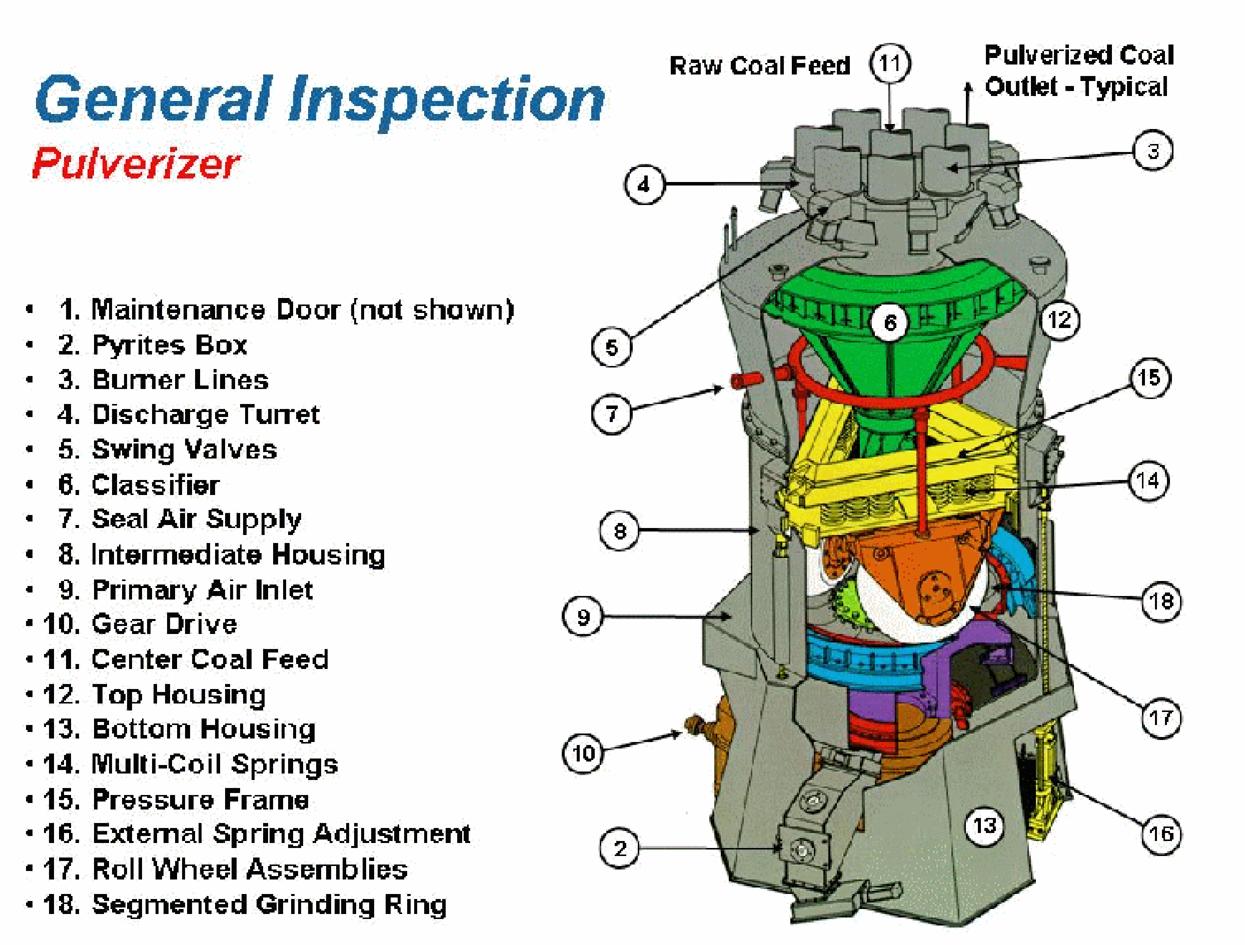


Babcock and Wilcox Roll Wheel Pulverizers

Describe the B&W Roll Wheel style pulverizer

B&W has designed, manufactured and placed in operation more than 1,100 roll wheel pulverizers since its introduction in 1972. They range in size from 37,000 pounds of coal per hour to 230,000 pounds of coal per hour.





General Inspection

Pulverizer

- 1. Maintenance Door (not shown)
- 2. Pyrites Box
- 3. Burner Lines
- 4. Discharge Turret
- 5. Swing Valves
- 6. Classifier
- 7. Seal Air Supply
- 8. Intermediate Housing
- 9. Primary Air Inlet
- 10. Gear Drive
- 11. Center Coal Feed
- 12. Top Housing
- 13. Bottom Housing
- 14. Multi-Coil Springs
- 15. Pressure Frame
- 16. External Spring Adjustment
- 17. Roll Wheel Assemblies
- 18. Segmented Grinding Ring

To prevent excessive maintenance in a pulverized fuel furnace, what type of refractory should be used?

To prevent excessive maintenance in a pulverized fuel furnace use waterwalls.

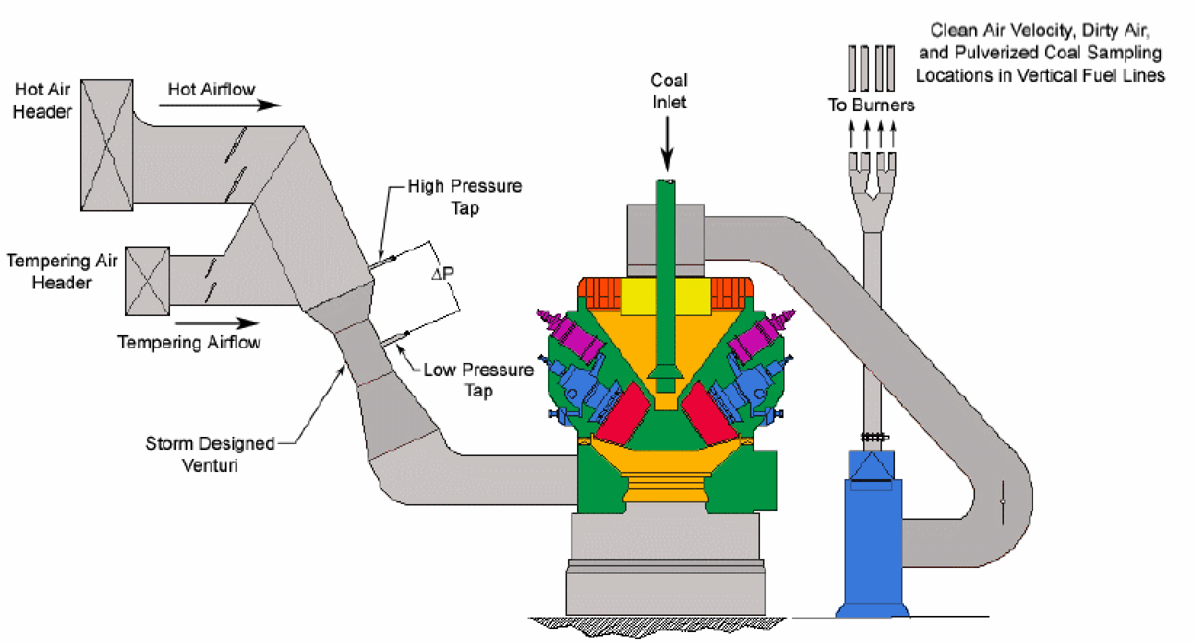
Where does coal drying take place in a unit system?

In the mill. The air in the mill performs three functions: It dries the coal; It helps classify the pulverized coal leaving the grinding elements; and It transports the finished product to the burners.

Honeywell Flame Safeguard Controls page 34

How do you adjust the temperature of the coal/air mixture leaving the pulverizer?

The adjustment is made by adjusting the tempering air damper.



What is the present minimum pounds of steam an hour necessary to successfully use a pulverized coal boiler?

The minimum amount of steam with pulverized coal is 100,000 pounds of steam per hour.

Honeywell Flame Safeguard Controls page 47

Table 24-2 shows a minimum of 35,000 pounds of steam an hour. On capacities above 150,000 pounds of steam per hour, practically all units burning bituminous coal are pulverized coal fired

Blue Combustion Engineering page 24·6

The Hardgrove and the Ball Mill Method are two means of determining what characteristic of coal?

Grindability

Blue Combustion Engineering page 2·8

What is Hardgrove Grindability?

Grindability is a term used to measure the ease of pulverizing a coal, in comparison with coals chosen as standards. In the Hardgrove test, the industry standard, a prepared sample of coal receives a definite amount of grinding energy in a laboratory pulverizer: results are measured by weighing the amount passing through a 200-mesh sieve. Multiplying weight passing the sieve by 6.93 and adding 13 to the product gives the Hardgrove Grindability.

Power Feb. 1974 page S-8

Grindability is determined by placing a 50 gram sample of air-dried coal, sized to minus 16 and plus 30 mesh, in the mortar of a test machine (small mill). After turning the machine through 60 revolutions the sample is removed and screened. The quantity passing a 300 mesh sieve is used to determine the hard grove grindability index by the following formula: $G = 6.93\,W + 13$

Where W is the weight in grams of the sample that passes a 200 mesh sieve.

Kent’s 12th edition page 7-83

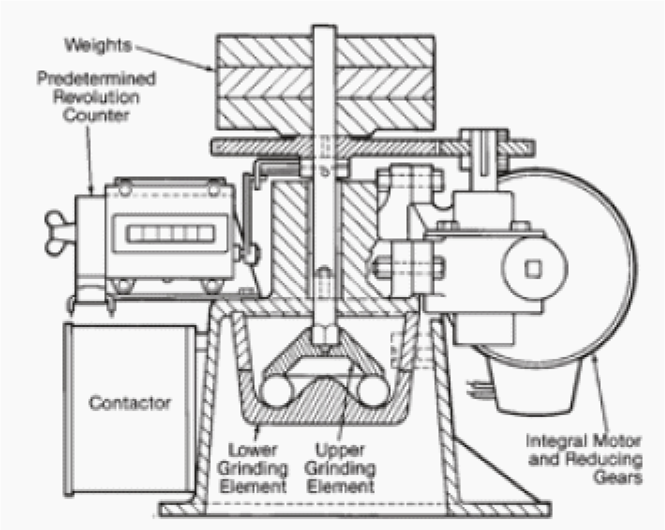
Why is the grindability of coal important to an Engineer?

The harder the coal, the more energy, (and therefore the more cost) it will take to get a satisfactory result in the furnace. Also, the longer it takes to grind to specification the longer it will take to respond to load increases.

The hardness of coal, or grindability, is a relative measure of the energy required for crushing. For lack of an exact law governing the energy required for crushing and a simple method for determining new surface, it has been desirable to predict mill-grinding performance on the basis of grindability and 200 mesh sieve fineness rather than on the surface area produced.

Kent’s 12th edition page 7-83

Modern Ball Mill Hardgrove Grindability Tester

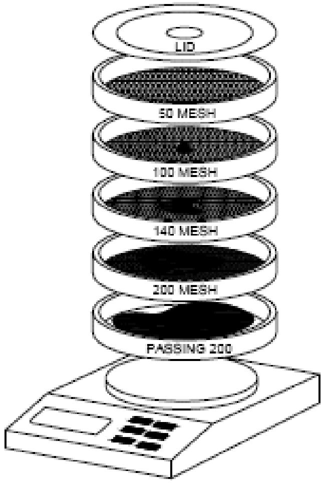

Weights
Predetermined Revolution Counter
Contactor
Lower Grinding Element
Upper Grinding Element
Integral Motor and Reducing Gears

Ball and Race style Hardgrove tester

What is 200 mesh?

A 200 mesh screen has 200 openings per linear inch or 40,000 openings per square inch.
It is used to govern the fineness to which coal must be ground for pulverization.

Blue Combustion Engineering page 7·7



After Drying place 50 grams of coal on stacked 50, 100, 140, and 200 mesh sieves and shake for 30 minutes

Why is it necessary to pulverize coal so that it will pass through a 200 mesh screen?

It is necessary to pulverize fuel so that it will pass through a 200 mesh screen so that ignition is rapid and sure. The preparation of coal to make it satisfactory for burning in suspension requires the presence of sufficient fine particles to insure prompt ignition.

Blue Combustion Engineering page 7·8

Completeness of combustion is a function of the uniform distribution of fuel and air, turbulence imparted to the fuel and air mixture, quantity of excess air, type of firing employed and fineness of pulverization.

Blue Combustion Engineering page 8·4

Why do most pulverizer specifications require an output of not more than 2% plus 50-mesh coal?

Many engineers now specify the percentage through 50 mesh, usually putting the lower limit at 98%.

Regardless of the percentage of minus 200 mesh, as little as 5% plus 50-mesh may result in slagging and increased combustible loss.

Blue Combustion Engineering page 7·8

Why isn't coal usually pulverized finer than 65% through 200 mesh and 99% through 40 mesh?

It is wasteful of energy to pulverize coal finer than required to obtain satisfactory combustion.

Steam Plant Operation by Woodruff and Lammers 5th edition Page 163

Some large furnaces may operate satisfactorily on high-volatile coal as coarse as 65 percent minus 200 mesh.

Blue Combustion Engineering page 7·8

Which should be ground to a greater degree of fineness, low volatile coals or high volatile coals?

Low volatile coal. High volatile coals ignite more readily than those with a low volatile content; therefore, high volatile coals do not require the same degree of pulverization as low volatile coals

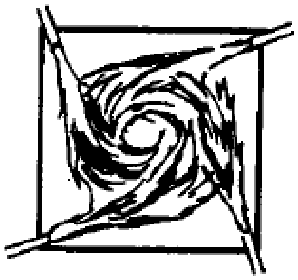
Blue Combustion Engineering page 7·8

What type of firing arrangement inside a boiler gives the best turbulence - horizontal, vertical, or tangential?

With tangential firing or opposed firing, the flame from two or more burners are directed at the same spot, creating a highly turbulent (swirling and rolling) furnace condition that thoroughly mixes the fuel and combustion air.

Tangential firing provides an extremely rapid, turbulent combustion with short flame lengths. Heat liberation rates sometimes exceed 35 MBH per cu.ft. The furnace temperature is lower than with vertical or horizontal firing.

Shields, pages 211-212



Tangential firing
(top view)

The Tangential System uses four burners, one in each corner of the furnace and in the same horizontal plane. From 25 to 50% of the air supply is primary air.

Kent's 11th edition page 4-32

What is the common term used for so called "tangential firing"

Corner firing

Blue Combustion Engineering page 9·43

What are the uses of primary air in a pulverized fuel unit?

After the coal is pulverized, the coal air mixture passes through piping to the burners. The air which carries the coal is called primary air. It constitutes about 20% of the total air required for combustion. The other 80% is known as secondary.

I.U.O.E. Fuels, Oils and Lubricants page 6-2-17

Preheated air from an outside source is introduced to the mill through the windbox. Once it is in the mill, it is called primary air, its purpose being to dry the fuel and transport it to the burner for combustion.

Detroit Edison Steam Course Fuel Burning Equipment page 33

Primary air serves two purposes. The air, under pressure greater than atmospheric, transports the fuel from the pulverizers to the burners, and also provides the initial air supply for combustion at approximately 15 to 20% of the air needed for complete combustion.

Detroit Edison Steam Course Fuel Burning Equipment page 20

At maximum load about 10% of the air required for combustion, with the combination impact and attrition pulverizer (Riley Stoker Corp.) is supplied by the pulverizer.

Croft Boilers page 245

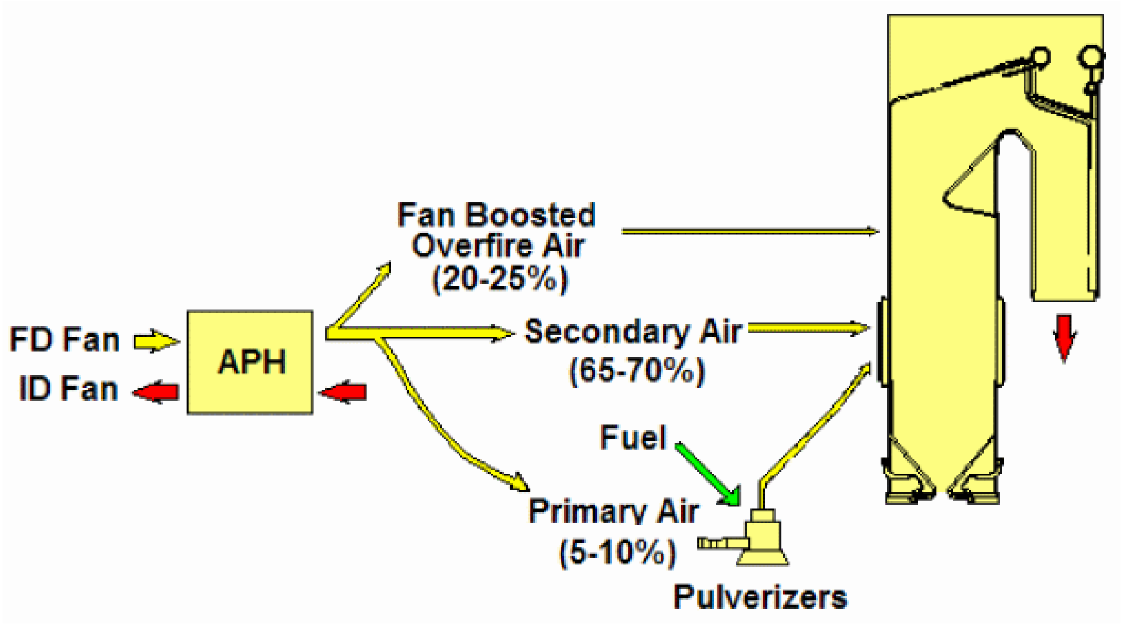
Where does the primary and secondary air come from?

A forced draft fan directs the air through a air preheater where 20% of the air which is primary air is used to dry and carry the coal through the pulverizer and to the burner.

The rest of the air which is 80%, is the secondary air which combines with the primary air and coal at the burner.

The primary air enters the mill from a duct taken from the forced draft fan and if a fan is used in addition to the forced draft fan it is known as the primary air fan. The primary air fan may take its suction from the discharge of the forced draft fan or directly from the air pre-heater.

Blue Combustion Engineering. page 26·8 and 26·9



What temperature is the primary air before the pulverizer?

Preheated air may be supplied to the mill at a temperature as high as 600 degrees Fahrenheit.

Power Plant Engineering page 1.174

In storage systems the temperature limits are about 110 degrees to 130 degrees Fahrenheit in order to avoid the possibility of a bin fire.

What is the outlet temperature of the coal-air mixture from the pulverizer?

The outlet temperature for direct firing methods should not exceed 150 F to 180 F for most designs.

Detroit Edison Steam Course Fuel Burning Equipment page 39

Explain why primary air is used

Primary air serves two purposes. The air, under pressure greater than atmospheric, transports the fuel from the pulverizers to the burners, and also provides the initial air supply for combustion at approximately 15 to 20% of the air needed for complete combustion.

Detroit Edison Steam Course - Fuels and Combustion page 20

If you lose a burner in a tangentially fired boiler, what should you do to maintain proper firing?

The correct procedure is to remove the fire on the opposite side of the furnace.

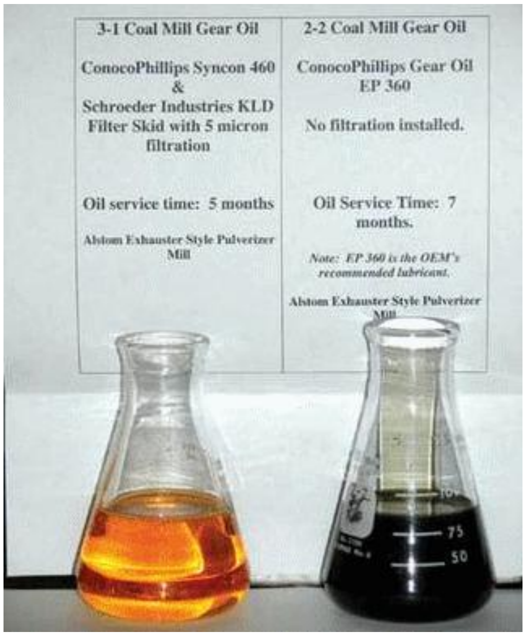
What type of oil is used on the gears of pulverizers?

A synthetic oil with a base of silicone, polyalkylene oxide (glycols), or, polyethers.

I.U.O.E. Fuels, Oils and Lubricants page 6.6.15

"Raymond Bowl Mill" - worm-gear drive uses a high stable non-corrosive gear lube with a lead naphthanate base having a viscosity of 85-95 SSU.

Mistersky - Operations Manual


3-1 Coal Mill Gear Oil
ConocoPhillips Syncon 460 & Schroeder Industries KLD Filter Skid with 5 micron filtration
Oil service time: 5 months
Alstom Exhauster Style Pulverizer Mill
2-2 Coal Mill Gear Oil
ConocoPhillips Gear Oil EP 360
No filtration installed.
Oil Service Time: 7 months.
Note: EP 360 is the OEM's recommended lubricant.
Alstom Exhauster Style Pulverizer Mill
75
50

From the mill to the burner what psi should be maintained?

The pressure in the coal/air delivery tubes from the mill to the burner should be maintained at 18 to 21 inches water gauge with a balanced furnace design.

Power Plant Engineering page 1.175

How do you clean a pulverizer?

If the air-fuel mixture leaving the mill at the time of shut-down is above 160 degrees Fahrenheit and there is no fire, the mill should be cleaned out by hand as soon after the shut-down as possible. If the air-fuel mixture is below 160 degrees Fahrenheit at the time of shut-down no immediate danger of fire exists, provided the mill is restarted within a 3 hour period. In a ball type mill when the grinding elements and the coal are intermixed, the contents of the mill may be drenched with water to avoid a mill fire.

After a fire in a mill and the mill temperature is low, vent the mill to remove any gases present then clean out the mill, plenum chamber, inlet and outlet piping, exhauster fan if applicable and mill feeder all by hand. Never use compressed air when pulverized fuel is present and make sure equipment is locked-out before work begins.

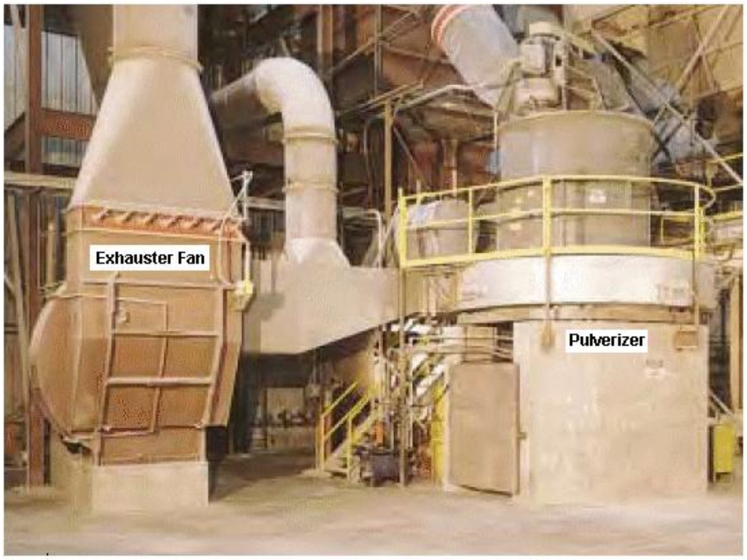
Detroit Edison Steam Course "Boiler Operation" page 6 and 7 Questions 28 & 30

Cleaning the pulverized coal from the roll wheel pulverizer

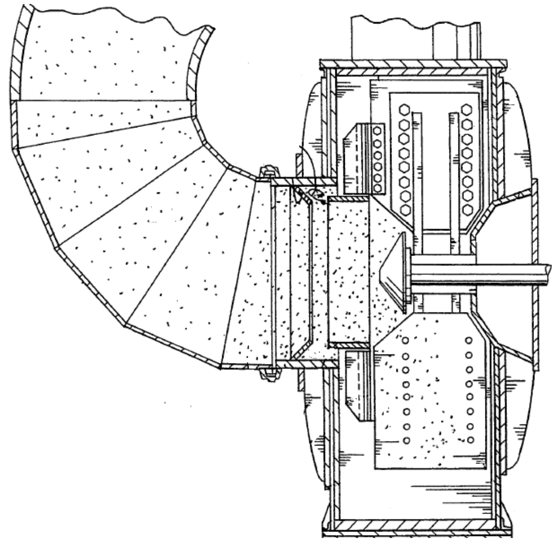
What is an exhauster?

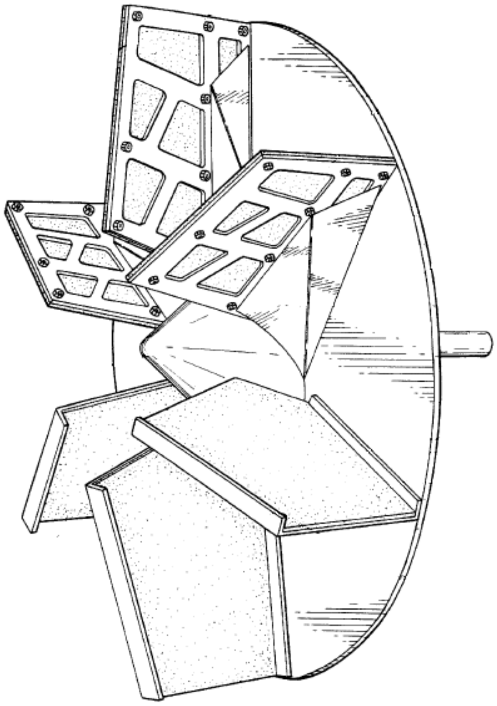
It is a fan connected to the outlet of a pulverizer and used to draw air through a pulverizer.

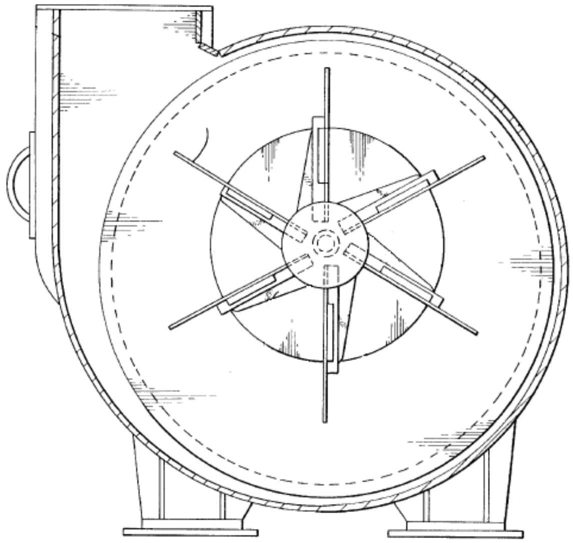
Glossary of Technical Terms B-l



Raymond Roller Mill







Different views of the rugged exhauster fan

What purpose does air serve in a pulverizer?

Preheated air dries the coal, helps sifts the coal and transports the pulverized fuel to the burner.

Detroit Edison Steam Course "Fuel Burning Equipment" page 22

Which coal must be ground finer for pulverization, lignite, anthracite, or bituminous?

anthracite

The fineness to which coals should be pulverized will depend on many factors. High volatile coals ignite more readily than those with a low volatile content. Therefore, they do not require the same degree of fine pulverization. Anthracite is a low volatile hard coal and needs greater pulverization.

Blue Combustion Engineering page 7·8

How is the first coal mill warmed, when going on line for the first time?

A heat exchanger could be placed in the duct work to the mill. Heat provided by a small auxiliary boiler for start-up purposes or electric coils can be used.

The most common is to bring the boiler unit up on oil or gas igniters thus using the heat from the air preheater to warm the mill.

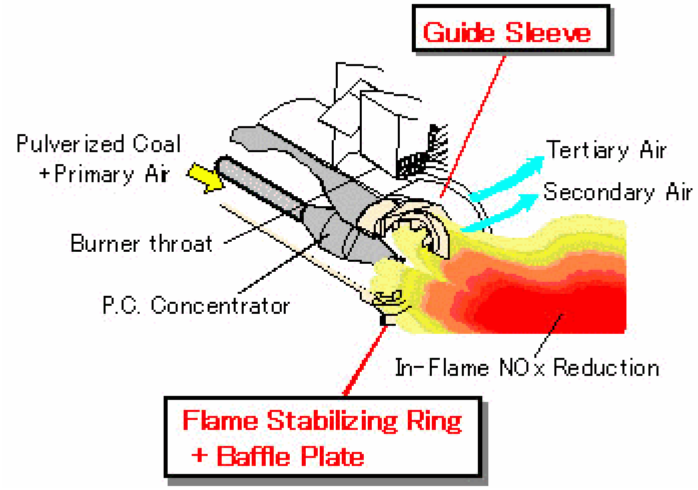
Don't overheat the mill, temper air supply during start-up with ambient air temperature.

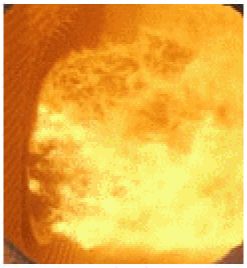
Joe Grubb

What is tertiary air?

Modern practice seems to favor either high velocity steam or air jets above the fuel bed to obtain turbulence, usually known as overfire air or tertiary air. The amount of excess air introduced to the furnace in this manner is governed by a great many factors, the most important of which is an analysis of the flue gasses. In most cases, the best results are obtained when the flue gasses show just a trace of CO_2. Tertiary air is a third air supply and is generally used to control the ignition of the fuel at the burner. When it is used, the normal point of admission is from the wind box of the burner, and its quantity is regulated by dampers. Burners of this type are called "fan tail" burners because of the shape of the flame.

Detroit Edison Steam Course, Vertical Burners

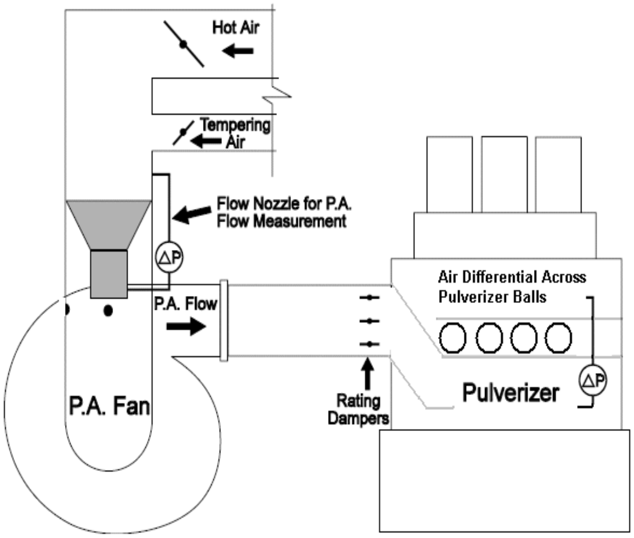




How is coal feed to a mill regulated?

Coal feed to the mill is controlled by draft loss (mill differential) across the mill. The draft loss may be used to actuate either an air or electric controller to control the mill feeder.
1. The automatic operation control system senses a change in load.
2. It sends a signal to open the primary air fan damper. (The primary air through the pulverizer is controlled so that it is proportional to the load demand)
3. As air flow increases draft loss decreases. This "mill differential" is sensed by the mill feed control and more coal is fed to the pulverizer. In this way a predetermined air coal ratio is maintained for any given load.

Steam, Its Generation and Use by Babcock and Wilcox page 17 - 7 Blue Combustion Engineering page 7·31
Detroit Edison Steam Course fuel Burning Equipment page 38


Hot Air
Tempering Air
Flow Nozzle for P.A. Flow Measurement
ΔP
P.A. Flow
P.A. Fan
Rating Dampers
Air Differential Across Pulverizer Balls
ΔP
Pulverizer

Delta P shown in the drawing as Δ P is the differential pressure across two points of measurement.

Explain start up a cold boiler on pulverized coal with no other fuel available

The exact procedure for lighting a pulverized fuel furnace depends to some extent upon the types of pulverizers, burners, and other equipment. There are certain general practices which are common to all. First, operate the induced draft fan and set the dampers to produce a furnace draft sufficient to prevent a pressure from being developed when the fire is lighted. Then insert the lighted torch and make sure it is producing sufficient flame in the path of the pulverized coal. Now start the pulverizer and feeder, and adjust the flow of primary air and the mill coal level to supply a rich mixture to the burner. Regulate the coal and air supply to the burner and maintain as rich a mixture as possible without smoke until the furnace has been heated. Do not depend upon hot walls or the fire from an adjacent burner to light a pulverized fuel burner. Use a lighting torch for each burner. If the coal as it is discharged from a burner fails to ignite after even a few seconds, the furnace will be filled with an explosive mixture. When this occurs, it is necessary to operate the induced draft fan until the explosive mixture has been removed. Care and judgment on the part of the operators is necessary during the warming up period. There is a low limit of output below which a given pulverizer mill cannot be satisfactorily operated. When the primary air drops below a minimum velocity it fails to remove sufficient coal from the mill and a lean mixture results. This minimum mill output usually results in too high a firing rate during the warming up period. The only solution is to fire the boiler at the lowest rating, intermittently and frequently enough to bring the unit on line in the specified time. Safety precautions and procedures must be carefully followed during each lighting.

Steam Plant Operation by Woodruff and Lammers 8th edition page 301

What would you do if a burner from a pulverizer failed to light immediately?

Should the fuel fail to ignite immediately, shut off the fuel feeder, pulverizer, pulverizer fan, and ignition torch and close the air-control valve. Allow at least 5 minutes for the furnace to clear itself of pulverized fuel with an air flow of not less than 50% of that required for full load operation.

ASME Section VII, Care of Power Boilers. Section C6.402(b).

What precautions should be taken when wet coal is to be fed to a mill?

Increasing the inlet air temperature to the mill just prior to admitting wet coal will reduce the possibility of admitting low temperature coal/air mixture to the burner.

Steam Plant Operation by Woodruff and Lammers page 177

What would be an indication of wet coal in a mill?

Low coal/air discharge temperature from the mill may be an indication of wet coal being a admitted to the mill.

Steam Plant Operation by Woodruff and Lammers page 177

How do you detect a fire in a pulverizer?

A fire in a pulverizer may be detected by a sudden increase in the mill outlet temperature.

Joe Grubb notes

Pulverizer fires can range from minor to highly destructive depending on how quickly the fire is detected by the operator. Combustible material such as rags or wood can start a fire as well as uncollected pyrites in the pyrite trap in the bottom of the pulverizer.[3] These fires are usually detected by an increase in mill outlet temperature. Usually the fire can be extinguished by switching to cold air and increasing the coal feed. Thermocouples are attached to the outlet casing on the pulverizer and sound alarms when they are overheated. When there is a rapid increase in outlet temperature the mill hot air gate should be closed and the coal feeder should be put in hand control. If the outlet temperature does not drop in 15 minutes, cut off the coal feed and shut down the pulverizer. CO_2 can be pumped into the piping at inerting points to put out the fire. After the fire is out, the pulverizer must be inspected and cleaned of any burning embers and ash.[4] All the lubricants of the mill must be checked.

Another problem that can occur in the pulverizer is interruption in the feed of the coal. Interruptions in the coal feed can cause explosions in the pulverizers. Mill feed systems must be closely monitored. Most explosions occur when first starting the mill feeder, so great care must be taken when putting a pulverizer on the line. Coal can also smolder for many hour after a fire. Care must be taken when restarting a pulverizer after a fire for this reason.

1Joseph G. Singer, Combustion Fossil Power Systems, (Windsor, CT Combustion Engineering, Inc., 1981), p. 12.2Ibid, pg 12-2. 3Ibid. pg 20-9. 4Ibid. pg 20-9

How do you handle a fire in an operating pulverizer?

First, change to cold air operation while avoiding changes in air flow. Increase coal feed to maximum. If the temperature doesn't decrease tempering the coal feed can increase cooling effect. If no change in 15 minutes, isolate all air connections and put inerting steam on, or flood with carbon dioxide or dry chemical extinguishing agents.

Joe Grubb notes

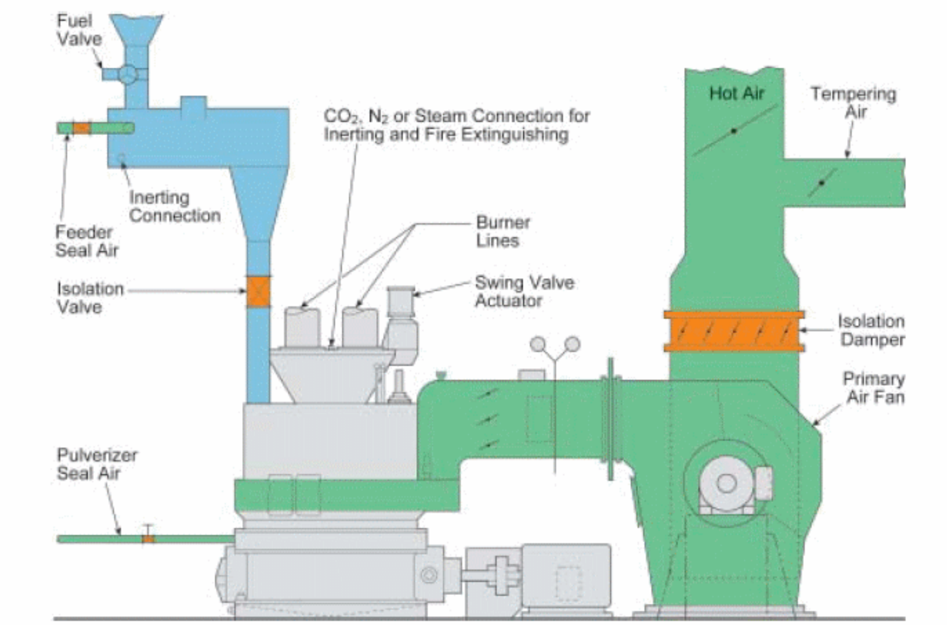
Fires in pulverizers during operation are very infrequent, but they sometimes occur as a result of fire originating in the raw coal bunker, of failure to clean up after welding, or of using inlet air to a pulverizer that is too high a temperature. The general procedure in this emergency is to reduce the supply of air so that the mixture in the mill will be too rich to support combustion. Fire in a pulverizer may be detected by the rapid rise in outlet temperature of the coal-and-air mixture. When this occurs, increase the fuel feed to a maximum and supply the pulverizer with cold air. Do not increase the air supply or reduce the fuel feed. If the temperature does not begin to return to normal within 15 minutes, shut down the pulverizer and close off the air supply. Close all outlets and, one at a time, open the cleanout or access doors and drench the interior with water, chemical fire extinguisher, or steam. Do not stand in front of the doors or inhale these gases, as they may be poisonous. Guard against possible explosion of the gases formed in the mill. After the fire is out, the material in the mill has been reduced to a temperature below the ignition point, and the pulverizer room has been ventilated, remove all coal, coke, and ash from the mill. Never use an air hose or a vacuum system in cleaning the pulverizer mill.

Steam Plant Operation by Woodruff and Lammers 5th edition page 277

If a fire is suspected in an operating pulverizer, the operator should proceed as follows: Increase the raw-fuel feed to the pulverizer capacity. The pulverizer is already operating at maximum capacity be sure that the fuel is not decreased. Change over from hot- to cold-air operation. Avoid increasing or making sudden changes in the air flow through the pulverizer and boiler.

If the temperature rise of the outlet air is checked and starts to return toward normal in a few minutes, continue operation until the normal outlet temperature is restored. The pulverizer capacity may then be reduced according to operating demands. However, if the pulverizer capacity is reduced, be sure that the air flow through the pulverizer is also reduced so as to keep a rich fuel-air mixture in the pulverizer.

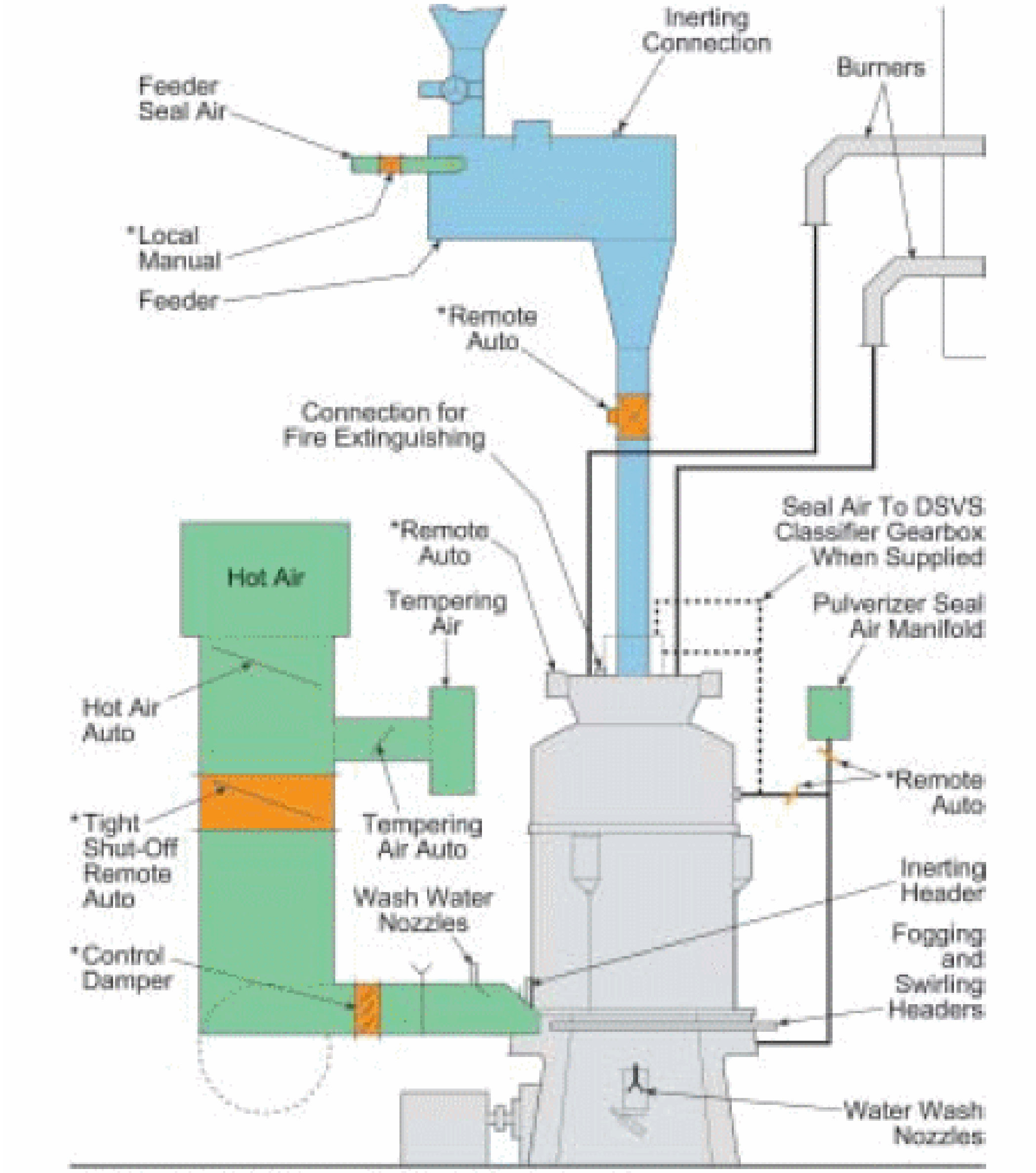
ASME Section VII Care of Power Boilers Section C6. 50 l(b)



Explain how to handle a fire in a shutdown pulverizer.

To extinguish a fire in a shutdown pulverizer: Close valves in all connecting lines to the pulverizer through which air may enter. Admit CO_2 gas and maintain required concentration or drench interior of pulverizer with the discharge from a chemical fire-extinguisher or steam directed through the access openings. The operator should stay out of direct line of the openings.

ASME Section VII Care of Power Boilers. Section C6.501(a)



Why has the central system been replaced with the unit system in pulverized firing?

The central system has two big disadvantages: The storage bin is a potential fire hazard. Spontaneous ignition almost always occurs if a bin full of powdered coal is left undisturbed for several days. After storing the coal for a few hours, caking occurs due to surface oxidation and the coal no longer flows freely. In the direct firing system now used, the pulverizer supplies only one furnace, and has no storage bin. Since there is no storage capacity, pulverizer operation fluctuates with load demand. The unit system is simpler, involving less equipment, so it reduces capital outlay. It also avoids the potential fire hazard and caking of the bin. The quantity of pulverized coal in the mill never exceeds a minimal amount, and piping between the mill and the furnace is short.

Honeywell Flame Safeguard Controls page 34

Start a "Raymond Bowl Mill."

a. Check oil levels. (worm-gear housing and roller journals)

b. Start with a fairly high setting on the mill feeder. Let the mill get up to speed before cutting in the feed. On a direct fired installation after ignition takes place the feed should be reduced to the desired amount.

c. The mill should be operated under suction at all times. A suction gauge connected in the mills side below the bowl and should be maintained at -1.5" water gauge

d. The gate in the tramp iron spout should not be held open. This will prevent the discharge of mill rejects.

e. For direct firing the mill outlet temperature ranges from 165º – 185º Fahrenheit depending on the coal.

f. Inspect gear housing temperature - temperature should not be over 160 º Fahrenheit increase water flow through cooling coil if temperature is too high.

g. In order to obtain rated capacity on the mill, it will be necessary to have sufficient hot air entering the mill to dry the coal, sufficient spring pressure to pulverize the coal.

h. The classifier deflector vanes must be set so as to obtain the fineness reasonably close to that for which the mill was designed.

Sometimes at Mistersky they have used wooden poles as a lever in the bowl, in order to get the rollers turning because they were so worn.

Mistersky - Operating Manual

Explain how a pulverizer is put on the line.

Provided the boiler is on line through the use of gas or oil burners then proceed as follows:

a. Start pulverizer and open hot-air dampers, allowing pulverizer to run five or ten minutes.

b. Open the outlet to burner damper, to obtain the best primary air pressure for lighting the burners - usually about 50% open.

c. Start the feeder. Operate it at full speed 20 seconds. Then cut back to half speed.

d. Watch the burners for appearance of coal, and be sure immediate ignition is obtained.

e. Adjust burners and forced draft pressure as required to bring the ignition point to the burners, and to obtain proper combustion conditions.

f. Reduce the firing rate on the oil or gas burners to minimum, using them as a pilot light until operating conditions are thoroughly stabilized.

g. Cut in a second pulverizer when the first is at 80% of its capacity.

Place a pulverizer on line.

This unit has no secondary fuel supply and one pulverizer. (It is off line.)

a. Start the forced draft and induced draft Adjust the forced draft dampers to obtain the proper air psi at the burners for lighting. Adjust induced draft to obtain about 0.1 in. wg. in the furnace.

b. Light the oil ignition torches.

c. Increase the furnace draft to 0.5 in. wg. to allow for the additional air which will be added when the pulverizer’s primary or exhauster fan is started. Adjust primary air psi to 18 to 28 inches water gauge.

d. Start the pulverizer, check the torches, then start the mill feeder. Run the mill feeder at full speed for 20 seconds then cut it back to half speed.

e. Watch the burner for appearance of coal and be sure ignition is obtained.

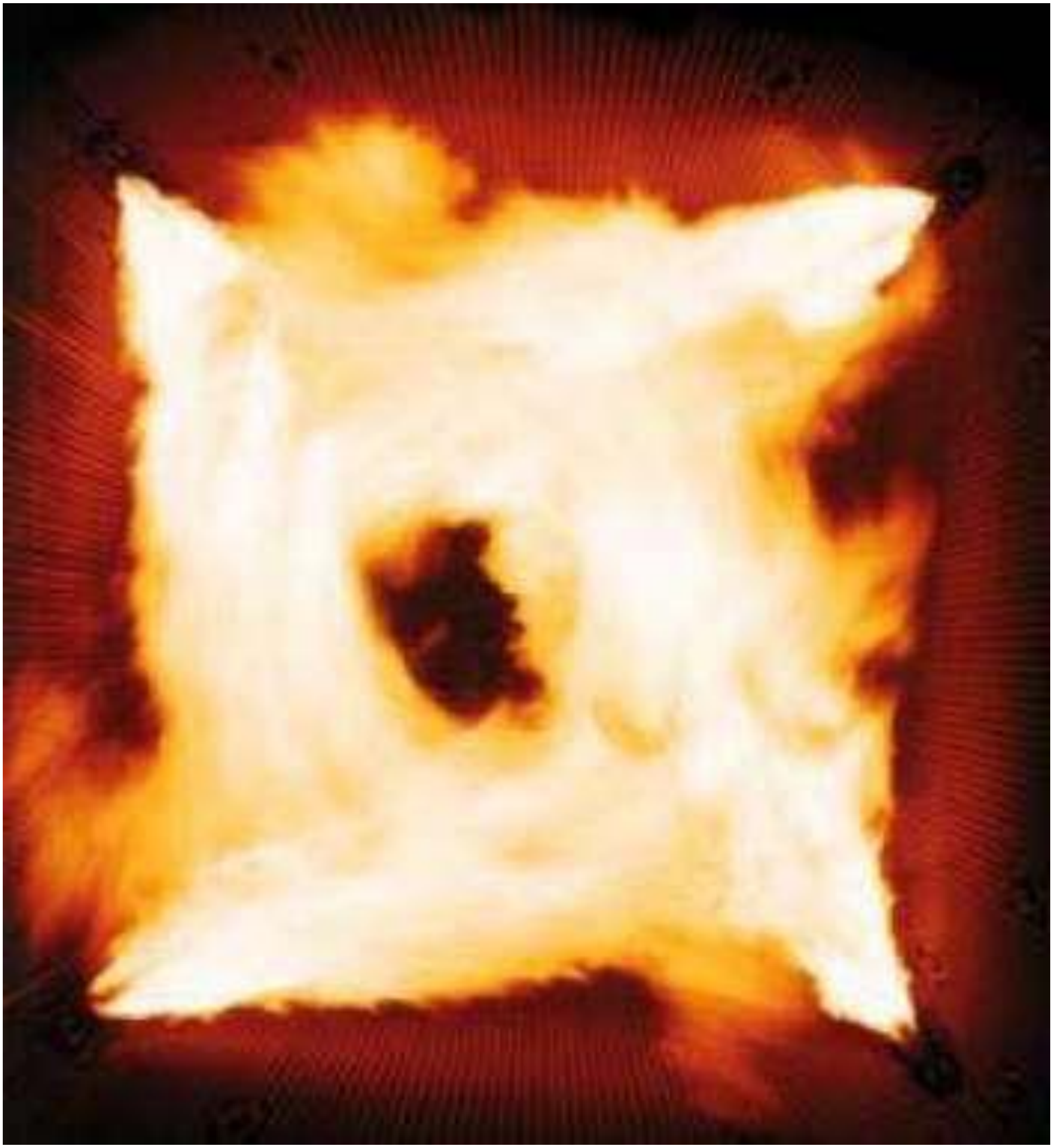
f. Allow oil torches to burn until stable ignition is obtained then turn off torches and cut back mill feed as far as possible.

Blue Combustion Engineering page 30·21

Explain the firing order for tangential set-up.

Bring up with ignition. Ignite all four corners at once. Start with lower deck then do upper deck.

Joe Grubb



Tangential flame in a pulverized coal Combustion Engineering Furnace

Chapter 10 Fuel Oil

How would you take a sample of oil?

During the unloading of any oil carrier, samples can be taken from the unloading line by either the drip or the slug method. A drip sample is the accumulated composite obtained by the continuous dripping through a small nipple or valve on the unloading line. The volume of the composite sample should range from 1 qt. to 1 gallon, depending upon the size of the carrier and on test requirements.

Slug samples are small quantities taken periodically from the unloading line. The number and frequency of these samples depend on unloading time. With a barge or tanker, hundreds of thousands of gallons are unloaded over several hours, so a slug sample should be taken about every 30 minutes; for a truck sample every 5 minutes. The separate samples are then mixed to form a composite.

Sample from a storage tank are taken through the manhole in the tank roof. The number of samples taken to form a composite depends on the depth of the oil in the tank, but never take fewer than three: top, center and bottom. Top samples should be taken at least 1 ft. below the surface; the bottom sample about 1 ft. from the tank bottom. This way, one will not pick up light or stratified oils floating at the surface or sludge lying on the bottom.

Direct sampling of oil barges and tanker requires sampling of each compartment at the top, center and bottom and then mixing the samples to form a composite. The procedure for direct sampling of trucks and tank cars is the same as for storage tanks. Here, three samples should be sufficient, because of the limited volume of oil.

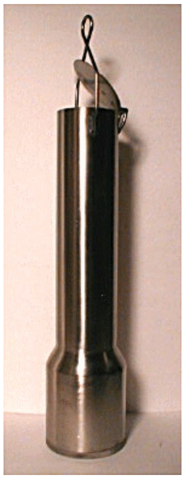
Power Plant Engineering page3.54

What tests are done when unloading oil from a barge?

Sulfur Test
API Gravity Test
Halogens Test* (Trash oil) for Chlorine, Fluorine, Iodine
BS&W Test
Percent water by distillation
Viscosity in SSU

*Use this test when using #6 trash oil, it tells if there is hazardous waste in the sample.

Chemist at Mistersky Fuel Oil



Sampler for Barges and Tankers

Taking an oil sample from the pipeline

Oil sample bottle

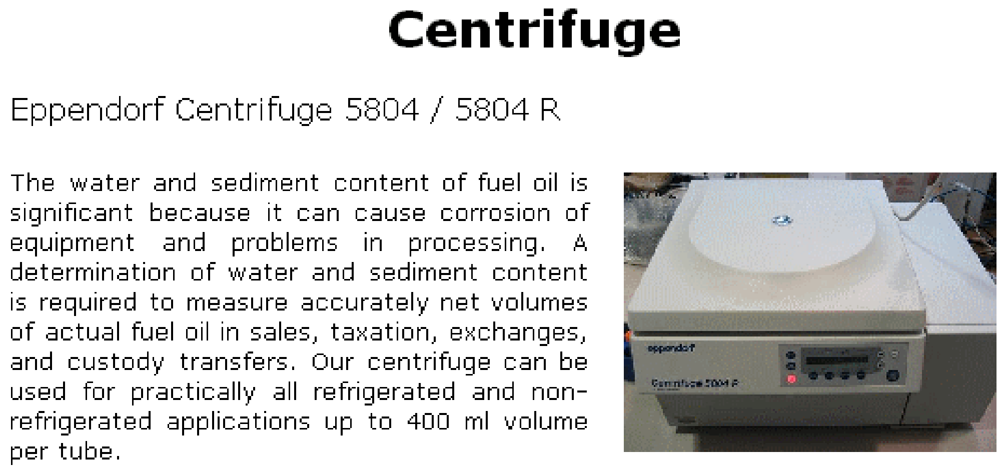
Oil samples

How do you check the moisture content in the oil?

Centrifuge Test: For large amounts, separate the moisture from the oil in a centrifuge and measure the volume.

Distillation: Toluene is mixed with the oil sample, it is heated, the oil and water separate and then the volume is measured.

Chemist at Mistersky



Centrifuge

Eppendorf Centrifuge 5804 / 5804 R

The water and sediment content of fuel oil is significant because it can cause corrosion of equipment and problems in processing. A determination of water and sediment content is required to measure accurately net volumes of actual fuel oil in sales, taxation, exchanges, and custody transfers. Our centrifuge can be used for practically all refrigerated and non-refrigerated applications up to 400 ml volume per tube.

Explain specific gravity.

Specific gravity is the ratio between the weight of any solid or liquid at 60 degrees Fahrenheit and the weight of an equal volume of pure water at 60 degrees Fahrenheit.

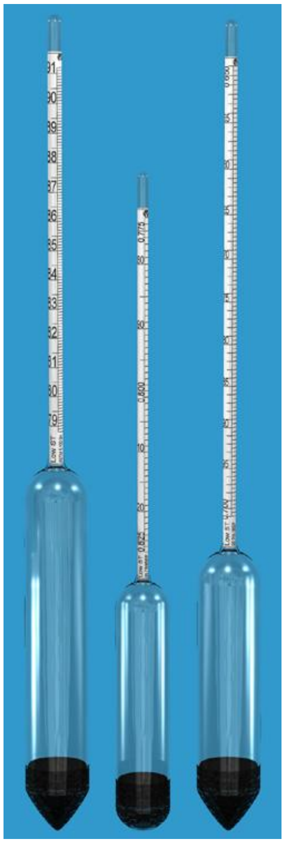
Specific gravity is the ratio between the weight of any gas at 60 degrees Fahrenheit and the weight of an equal volume of pure air at 60 degrees Fahrenheit.

Kent’s 12th edition page 2.47

What is meant by the specific gravity of a fuel?

Specific gravity is the weight ratio between a unit volume of oil
as compared with the same volume of water,
both at 60 degrees Fahrenheit

Detroit Edison Steam Course page 8. Fuels and Combustion. Question #40



Petroleum Hydrometers for determining specific gravity. They are dropped into a sample beaker and they float at different levels. The bottoms are weighted. The scale is then read to determine the specific gravity

What is the API gravity of #6 fuel oil?

The No. 5 oil is sometimes referred to as "bunker B" and No. 6 as "bunker C", although "bunker C" also frequently refers to oil heavier than 140 API.

#1 = 38 - 40 degrees API….136,000 BTU/gal.
#2 = 34 - 36 degrees API….138,500 BTU/gal.
#3 = 28 - 32 degrees API….141,000 BTU/gal.
#4 = 24 - 26 degrees API….145,000 BTU/gal.
#5 = 18 - 22 degrees API….146,500 BTU/gal.
#6 = 14 - 16 degrees API….148,000 BTU/gal.

Preheating Temperature for Fuel Oil

#4 = 150 degrees Fahrenheit at the burner
#5 = 175 degrees Fahrenheit at the burner
#6 = 275 degrees Fahrenheit at the burner

Because of the two Baume scales, the Bureaus governing fuel oils agreed to use the API scale for determining the gravity of light oils. Water is taken as 10 degrees API. Oils lighter than water have higher degrees API gravity, according to the formula.

$$\frac{(141.5)}{(\text{specific gravity @ 60 degrees Fahrenheit}) - 131.5} = \text{API degrees}$$

Steam Plant Operation by Woodruff and Lammers page 119

What is the flash point of #5 and #6 oil?

Flash point, varies with apparatus and procedure, and both must be specified when flash point is stated. The minimum flash point is usually controlled by law. If no legal requirements exist, then minimum values are:

#1 = 100 degrees Fahrenheit
#2 = 100 degrees Fahrenheit
#3 = 130 degrees Fahrenheit
#4 = 130 degrees Fahrenheit
#5 = 150 degrees Fahrenheit
#6 = 150 degrees Fahrenheit

Kent’s 12th edition page 2.46

Pensky-Martens Flashpoint tester

What is the difference between #5 and #6 fuel oil.

Gravity API
#6 = 12
#5 = 17

Specific Gravity
#6 = .9861
#5 = .9529

Weight lb/gallon
#6 = 8.212
#5 = 7.935
water = 8.333 lb/gal.

Temperature at Burner
#6 = up to 275 degrees Fahrenheit
#5 = 175 degrees Fahrenheit

#6 has a higher viscosity, higher sulfur content (It can weigh more than water), higher heating value, and a higher flash point than #5 fuel oil.

BTU/lb
#6 = 18,750
#5 = 18,950

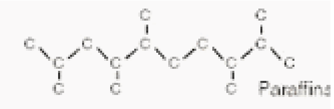
Steam Plant Operation by Woodruff and Lammers pages 119, 120

What is asphaltic, paraffinic, and naphthenic oil?

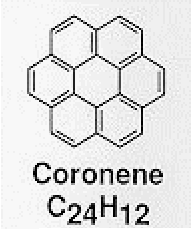
Crude petroleum from different oil fields has a different molecular structure of their hydrocarbons. Paraffin-base crude oils are composed mainly of chain-structured, paraffin hydrocarbons. Naphthenic-base or asphaltic-base crude oils contain large quantities of saturated, ring structured naphthenes. Aromatic-base oils contain many unsaturated ring-structured aromatics. Mixed-base or intermediate-base crude oils fall somewhere between the paraffin-base and naphthenic-base crude.

Except for heavy fuel oils, the type of crude involved has little effect on the products obtained and their use in the combustion process.

I.U.O.E., Fuel Oils and Lubricants, page 6-1-2



Paraffinic oil



Asphaltic Oil

What is the API of #6 fuel oil?

The specific gravity of fuel oil is used as a general index of its classification and quality. To determine specific gravity, the weight of a given volume of oil is divided by the weight of an equal volume of water, when both are at the same temperature.

Special laboratory determinations of fuel oil are made in terms of specific gravity. In practice, the gravity is measure by a hydrometer and is read in degrees Baume of API. The API scale, adopted by the American Petroleum Institute, is now generally accepted. Through its use specific gravity may be converted into degrees API by the use of the formula:

degrees API = 141.5/specific gravity at 60 degrees Fahrenheit /60 degrees Fahrenheit - 131.5
specific gravity of #6 = .97
API = 141.5/.97 - 131.5
degrees API = 145.9 - 131.5 = **14.4 degrees API**
API gravities of commercial fuel oil vary from 10 to 40.

I.U.O.E., Fuel Oils and Lubricants, page 6-1-9

In fuel oils, what happens to the specific gravity as the BTU content increases?

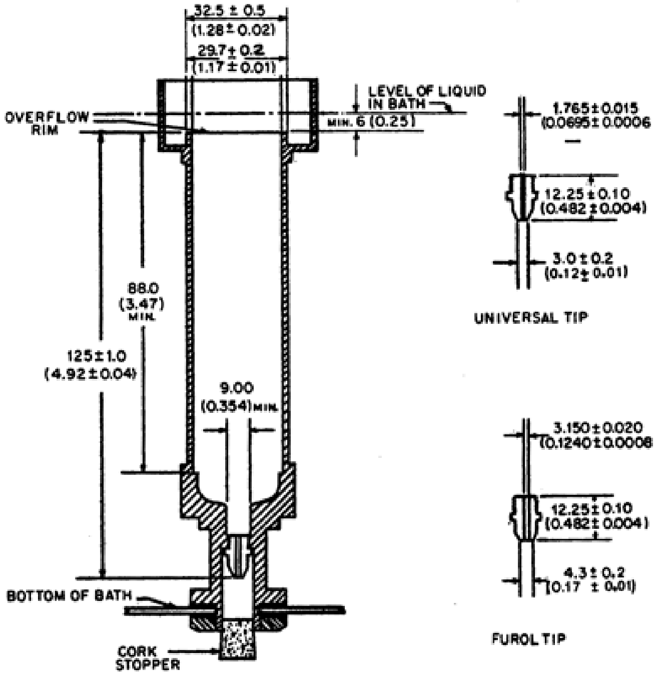
Heating value is expressed either in terms of BTU/gallon at 60 F, or in terms of BTU/lb. The heating value per pound varies inversely with the specific gravity of the fuel oil because the lighter oils contain more hydrogen. The heating value per gallon increases with the specific gravity because there is more weight per gallon. Thus, the specific gravity of the oil is an important item to consider when purchasing fuel oil. Specific gravity is the weight ratio between one unit volume of oil as compared with the same volume of water, both at 60 degrees Fahrenheit.

Detroit Edison Steam Course Fuels and Combustion

What is viscosity and how is it measured?

Viscosity is a measure of a substance's resistance to flow. As such, viscosity indicates ease of flow, or pumping, and ease of atomization. Standard laboratory procedures for determining viscosity are published by ASTM. Viscosity measurements are expressed as
Saybolt Seconds Universal (SSU), and
Saybolt Seconds Furol (SSF) . Each of these scales indicates the amount of time needed for a given amount of oil at a specific temperature to flow by gravity through a specific orifice or tube. The Saybolt Universal viscosimeter has a relatively small orifice and so is used for lighter oils. The Saybolt Furol viscosimeter, which is used for heavier oils, has a larger orifice. An increase in temperature lowers viscosity. Accordingly, heavy oils must be heated so they can be handled effectively in pumps and burners.

I.U.O.E., Fuels, Oils and Lubricants, page 6-1-6



Saybolt Universal and Saybolt Furol Viscosimeter

What is the BTU value of #1 through #6 oil per pound?

Heating Values: BTU/lb

#1………. 19,100 - 20,500
#2………. 18,700 - 20,400
#4. ……… 18,300 - 20,000
#5Light…. 18,500 – 19,500
#5Heavy... 18,500 – 19,300
#6………. 17,900 – 19,400

I.U.O.E. Fuels, Oils and Lubricants

What is the BTU value of #1 through #6 fuel oil per gallon?

Heating Values: BTU/gal.

#1……... 137,000 - 132,900 (I.U.O.E. Fuels, Oils and Lubricants page 6-1-10)
#2……… 141,800 - 137,000
#4……… 148,100 - 143,100
#5Light... 150,000 - 146,800
#5Heavy.. 152,000 - 149,400
#6……… 155,900 - 151,300

What is the average CO_2 reading when burning fuel oil?

The carbon dioxide in the flue gasses should be maintained at 10 to 14% without smoke.

Steam Plant Operation by Woodruff & Lammers page 192

What is the specific heat of fuel oil?

The specific heat or coefficient of thermal capacity of a substance is the number of BTU's that must be imparted to, or abstracted from each pound of the substance to change the temperature of the substance 1 degree degrees Fahrenheit. The specific heat for Kerosene, a fuel oil, is 0.50 BTU/lb degrees Fahrenheit

Croft Practical Heat

All things being equal, could you check the viscosity of oil quicker using a Saybolt Universal Viscosimeter or a Saybolt Furol Viscosimeter?

Saybolt Furol Viscosimeter. The saybolt Universal viscosimeter is used for fluids that have an efflux time greater than 32 seconds. although there is no maximum limit of flow time, for very viscous fluids, as heavy oils above 250 SUV (Saybolt Universal Viscosity), the viscosity is more conveniently measured by the Furol viscosimeter, similar to the Saybolt Universal, except that it has a larger diameter tube resulting in an efflux time approximately one-tenth that of the Saybolt Universal Viscosimeter The time in seconds for the efflux of fluid in the Furol viscosimeter is known as the Saybolt Furol Viscosity.

How is fuel oil classified?

The term fuel oil covers a wide range of liquid fuels, from kerosene to crude oil. The National Bureau of Standards has established specifications for five grades of fuel oil. These cover such items as flash and fire points, pour point, distillation temperature, etc. Grades #1, #2, and #4 are sometimes called light, medium and heavy domestic fuel oils. Grade #6 is commonly called "Bunker C" oil and this is heavy industrial fuel oil. It is usually specified by its viscosity. An average analysis of this fuel may be taken as: 87.3% carbon, 10.8% hydrogen, 1.2% sulfur, and 0.2 % nitrogen. The higher heating value of the fuel is taken at approximately 18,500 BTU per pound.

Detroit Edison Steam Course Fuels and Combustion page 8 Question #38

What are the important properties of fuel oil?

These are: specific gravity, heating value, viscosity, flash and fire points, sulfur content, moisture, ash content and pour point.

Detroit Edison Steam Course page 8. Fuels and Combustion, Question #39

How is the heating value of fuel oil expressed?

It is expressed either in terms of BTU per gallon at 60 degrees Fahrenheit, or in terms of BTU per pound. The heating value per pound varies inversely with the specific gravity of the fuel oil because the lighter oils contain more hydrogen. The heating value per gallon increases with the specific gravity because there is more weight per gallon. Thus, the specific gravity of the oil is an important item to consider when purchasing fuel oil.

Detroit Edison Steam Course page 9. Fuels and Combustion. Question #41

What does the viscosity of the fuel oil refer to?

Viscosity is defined as the measure of the resistance to flow. The greater the resistance, the longer it will take a unit volume of the oil to flow through an orifice of a given size. Up to 250 degrees Fahrenheit, the viscosity is nearly constant. Because of this, some standard temperature must be used when testing for viscosity; these standard temperatures are: 100 degrees Fahrenheit, 150 degrees Fahrenheit and 210 degrees Fahrenheit plus or minus 0.25 degrees Fahrenheit

Detroit Edison Steam Course Fuels and combustion page 9 Question #42

What is meant by 150 SSU at 210 degrees Fahrenheit?

This is a measure of viscosity, and it means that a 60 cc. sample of oil, when heated to 210 degrees Fahrenheit, requires 150 seconds to completely run through a standard size orifice in a Saybolt Universal viscosimeter. Since heavy fuel oil is extremely viscous and the time required for testing in a Universal viscosimeter is rather long, the viscosity is expressed a little differently. A Saybolt Furol viscosimeter is used and this differs from the Universal only in the fact that it has a larger orifice through which the oil may pass. 600 seconds Saybolt Universal is equal to 62 seconds Saybolt Furol.

Detroit Edison Steam Course page 9 Fuels and Combustion. Question #43

Explain flash point.

Flash point is the temperature to which oil must be heated to give off sufficient vapor to form a flammable mixture with air.

Kent’s 12th edition page 2.46

What is the difference between the flash point and the fire point of a fuel?

The flash point is the temperature at which sufficient vapor is given off, under certain standard conditions, to form a momentary flash when a flame is brought near the surface of the oil. The fire point is the temperature at which oil gives off enough vapor to burn continuously.

Detroit Edison Steam Course page 9. Fuels and Combustion. Question #44

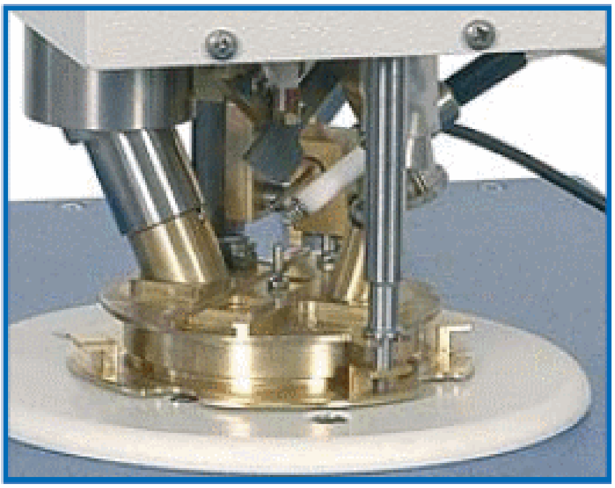
Explain a Pensky-Martin Test.

It is a test to determine the flash point of oil.

Heat a sample (heating element immersed in water) in a closed cup tester until sufficient gas is produced to cause a flash when a naked (flame) light is applied but not sufficient to sustain combustion. Record the temperature on the thermometer.

The Pensky Martens apparatus is used to determine the flash point of fuel oils, lubrication oils, asphalt and any other highly vicious petroleum products that require stirring during the testing procedure. The flash point of oil is the temperature at which gasses given off will flash when ignited. As such, flash point indicates the maximum temperature at which it can be stored and handled. Minimum permissible flash point usually is prescribed by state and local laws. Because light oils contain more hydrogen than heavy oils, they ignite more easily and so have lower flash points. Oil with a low flash point burns more readily than one with a high flash point. In the analyzer, the liquid sample is heated, its vapor is mixed with controlled flow of air and the mixture is fed into a spark chamber. As the liquid sample temperature, and therefore the vapor content, is increased the mixture will finally be ignited by the spark. This temperature is the flash point of the oil tested.

Grubb's Notes "Fuels and Combustion"



gas igniter &
electric auto-ignition device

Why is sulfur so much more undesirable in fuel oil than in coal?

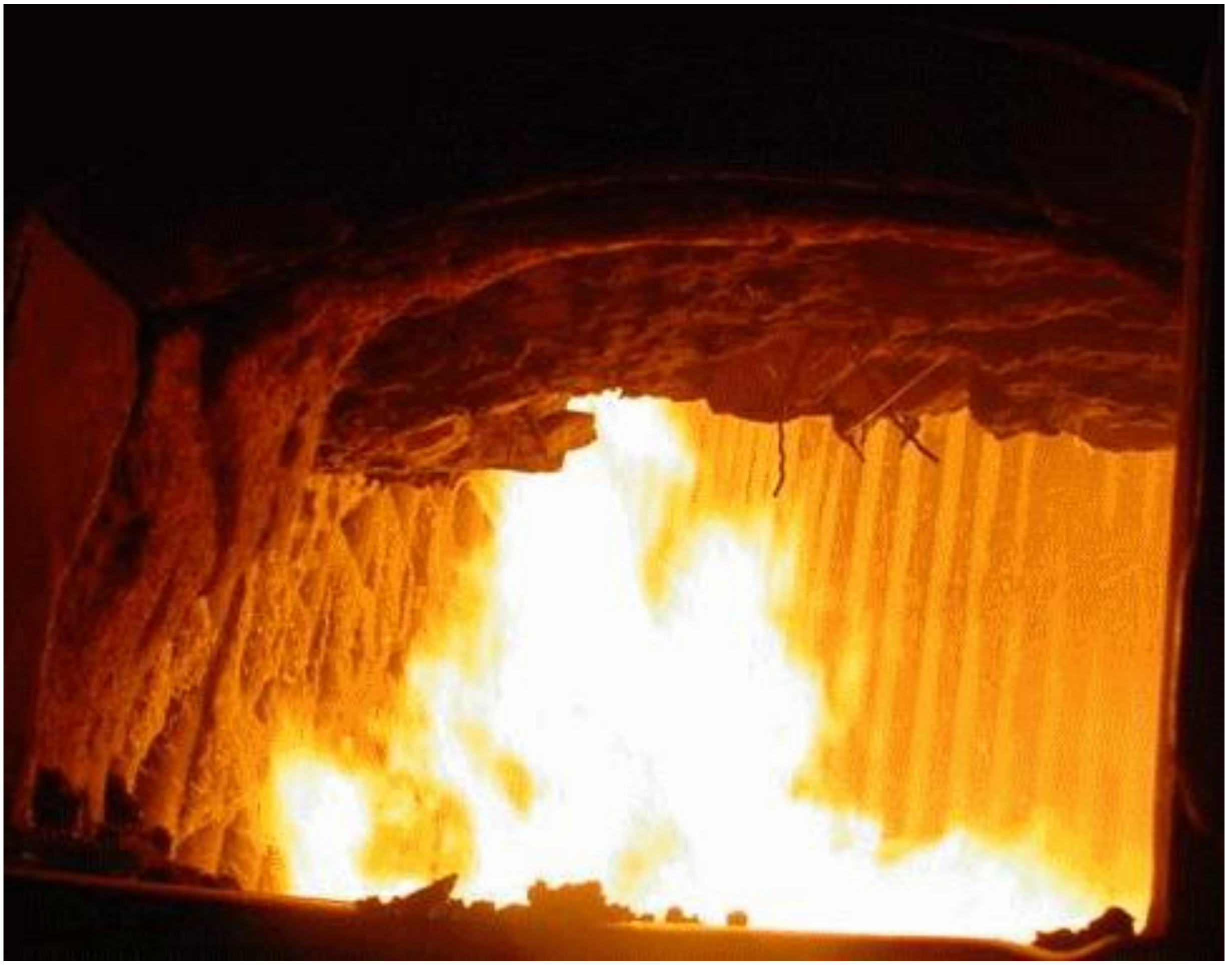
The product of the combustion of sulfur is an acid when mixed with water and this will attack the metal surfaces of economizers and air heaters. There is a greater tendency toward this attack when burning fuel oil because the hydrogen content of the oil is greater than that of coal. The result of this is a greater amount of water vapor in the flue gases.

Detroit Edison Steam Course Fuels and Combustion page 9 Question #45

Is there any ash or slag formed when fuel oil burns?

The residue of the combustion is called ash and it usually appears as slag on the boiler tubes. Fuel oil contains all of the solid impurities originally present in the crude oil. If these impurities contain a large proportion of salt, as they often do, they are fusible, and form slag on the tubes.

Detroit Edison Steam Course Fuels and Combustion page 10 Question #46



Slag on the tubes of an oil fired furnace

What is the pour point of oil?

Pour point is the lowest temperature at which oil will flow under prescribed conditions.

Kent's 12th edition page 2.46

The pour point of oil is the lowest temperature at which the oil will still flow when a sample in a cup is turned at a 45 degree angle

Is the pour point of an oil is where it begins to flow or where it ceases to flow?

Pour point is the lowest temperature at which oil **will flow** under prescribed conditions (ASTM D97-47)

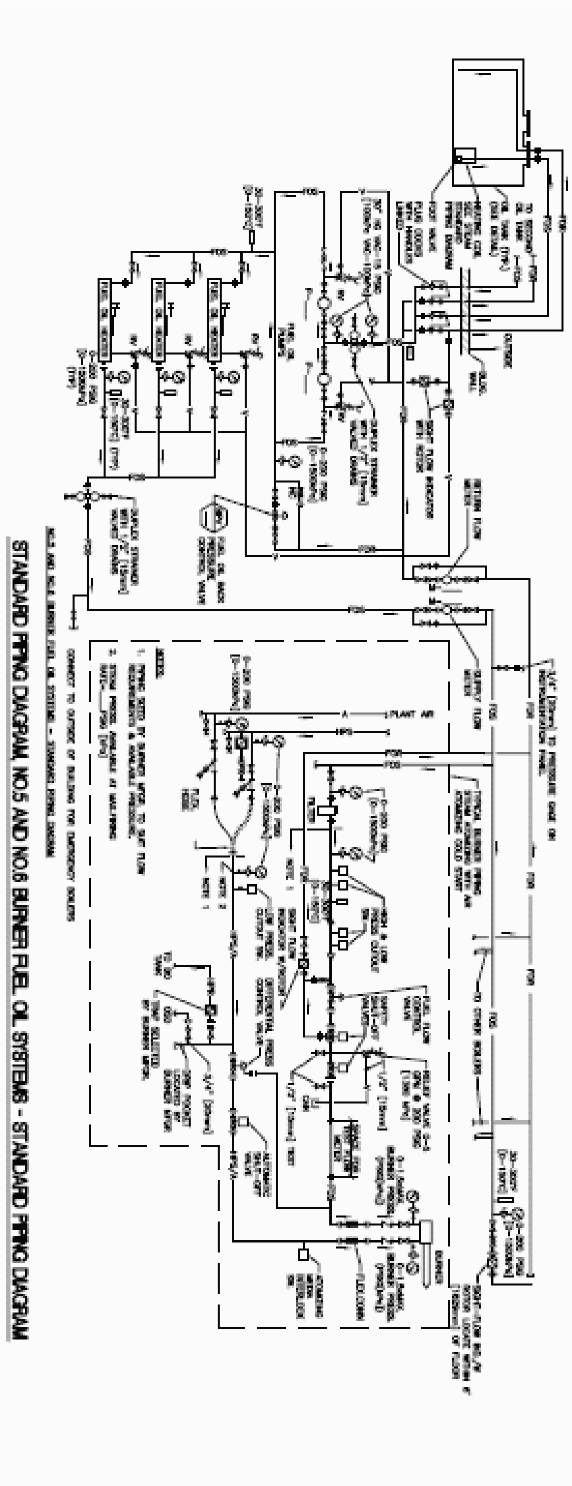
Kent's 12th page 2-46

What is the importance of knowing the pour point of fuel oil?

Congealed oil cannot be pumped through pipe lines and in cold climates this is a very important consideration because of outdoor storage.

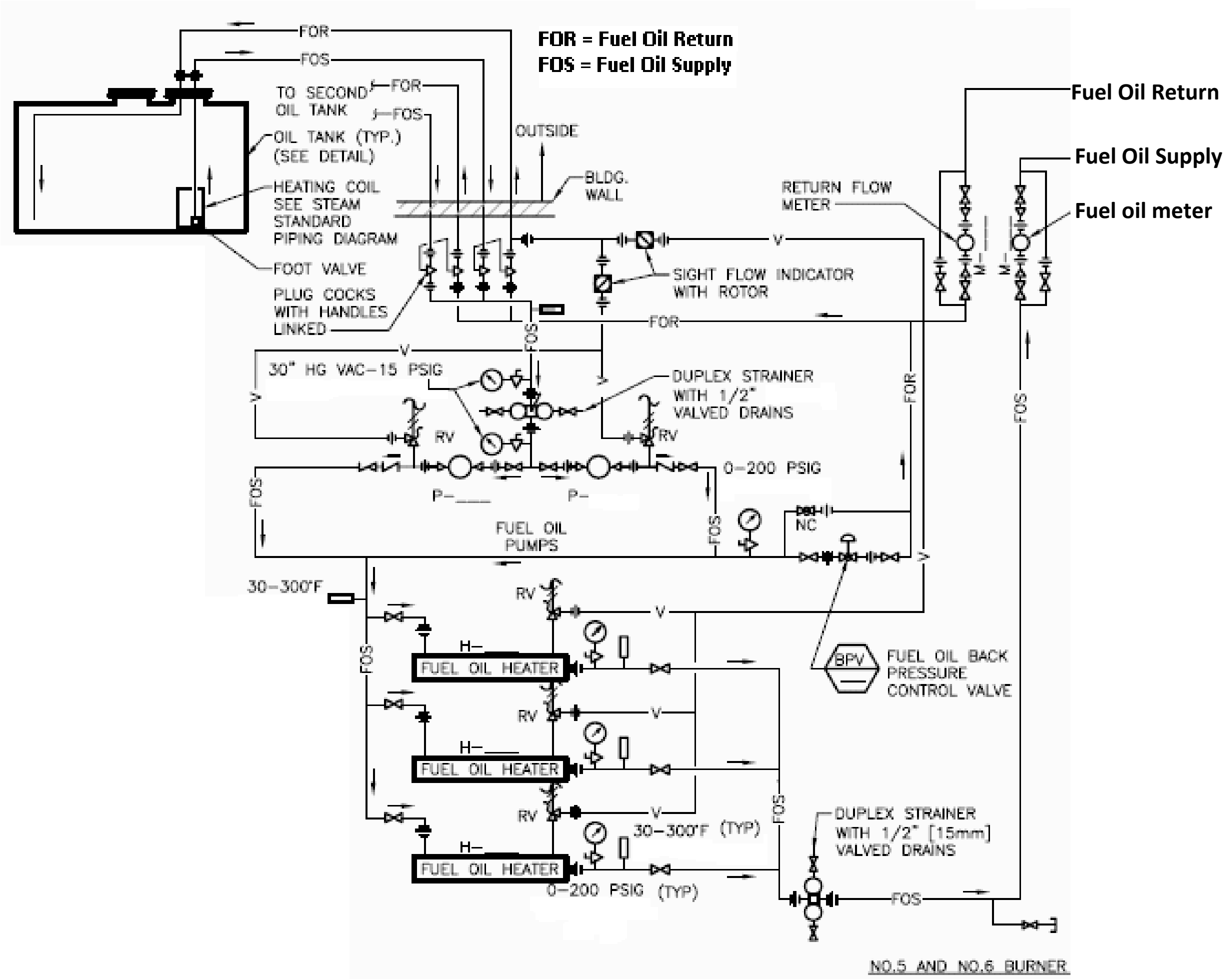
Detroit Edison Steam Course Fuels and Combustion page 10 Question #47

Demonstrating the pour point. The oil is just beginning to flow.

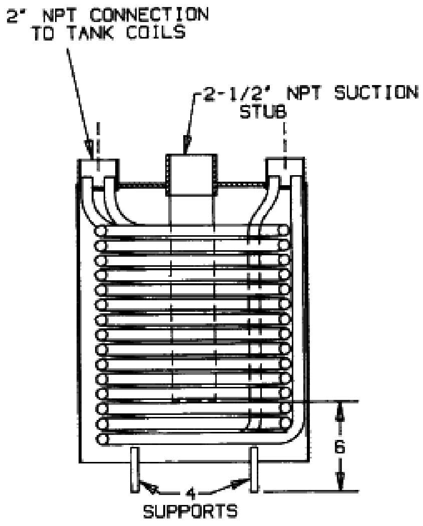

STANDARD PIPING DIAGRAM, NO.5 AND NO.6 BURNER FUEL OIL SYSTEMS - STANDARD PIPING DIAGRAM

A #6 fuel oil diagram that you should practice drawing for the exam.

For your License, you may have to draw a #6 fuel oil system. This is an excellent drawing that we will be going over step by step. It is split into two parts in order to get it on the page in a legible fashion. You can compare it to the full drawing above if you lose your way but the drawing is split by the dashed lines into the two parts. We will start at the fuel oil tank and travel the circuit from fuel oil supply to fuel oil return.



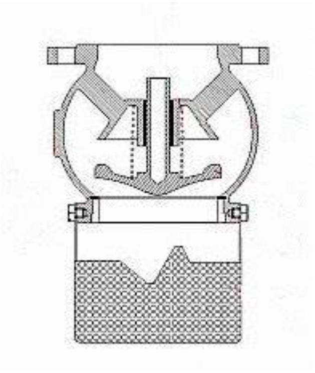
Starting with the fuel oil tank, the Fuel Oil Supply (FOS) is drawn from a few inches above the bottom of the tank to prevent sludge from being drawn into the pump. The suction line is surrounded by a steam and/or electric heater to get the #6 oil to flow. At room temperature, #6 fuel oil is like a very thick molasses or syrup and will not flow unless it is heated.



Steam coils surrounding the fuel oil suction at the bottom of the tank

The foot valve at the bottom of the tank keeps the pump primed.

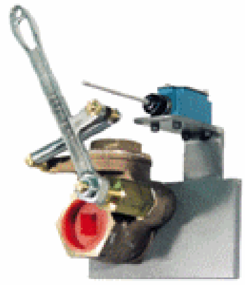
Foot Valve



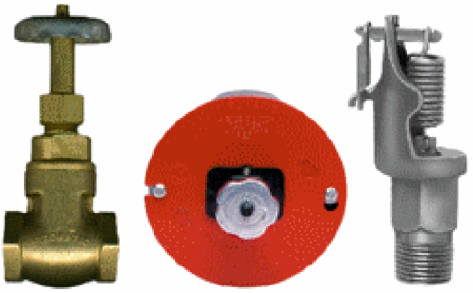
Foot Valve Diagram

The supply line is under a vacuum when the pump is operating. Any leaks in the piping will cause a loss of vacuum as noted on the 30”HG VAC 15 PSIG gauge. Just as the supply piping enters the powerhouse wall, there are special valves (plug cocks or other type valves with handles linked) with fusible links that will close in case of a fire in the powerhouse. These operate at 165° Fahrenheit. Below are some examples.

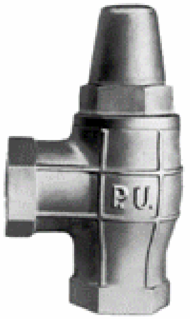
Don’t Feed the Fire
Stop the flow of the fuel



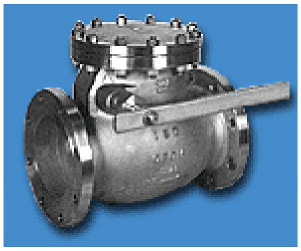
Lever Gate Valve (with end switch)



Fusomatic Valve, Cut-Off & Syphon Breaker

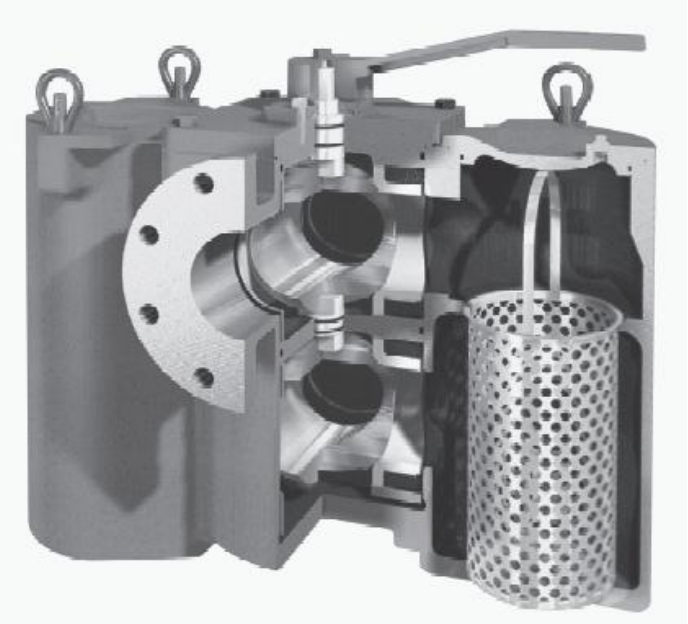


Anti-Syphon Valve

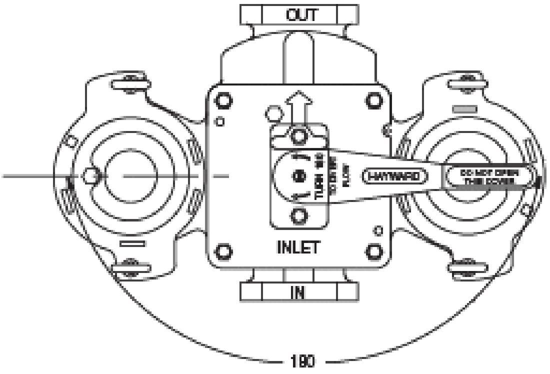


Fuseable Links

From the temperature actuated valves the oil goes through a set of duplex strainers with coarse screens. The holes are small enough to prevent damage to the fuel oil pumps. On both sides of the strainers are compound gauges that read in vacuum or pressure.

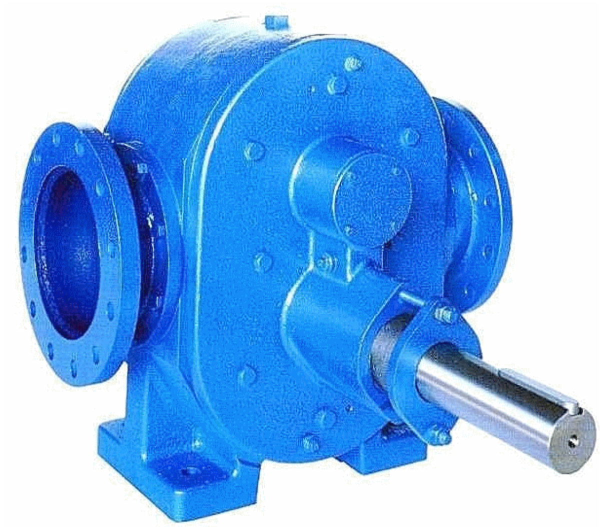


Duplex Oil Strainer

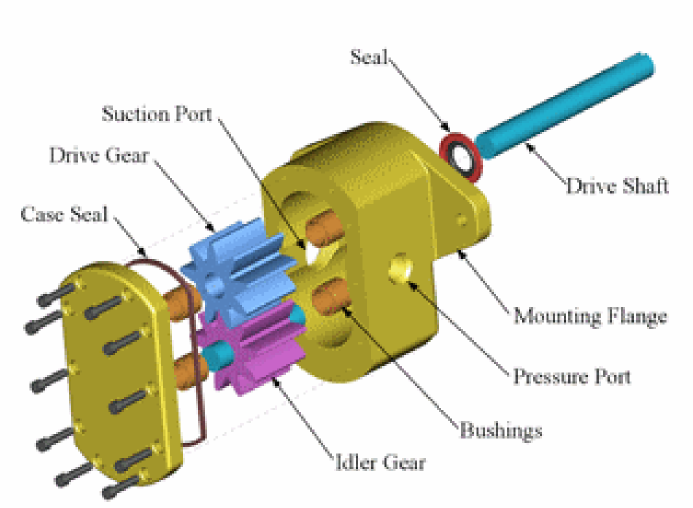


Turning the valve handle 180 degrees switches from one strainer to the other. The cover not under the handle can be cleaned.

Compound Gauge



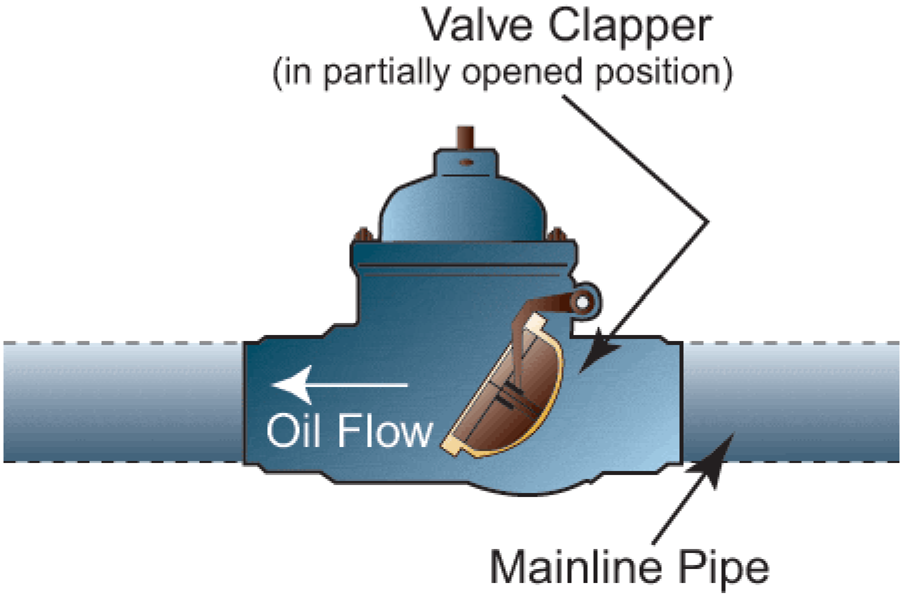
From the strainers, the oil passes through a gate valve and then enters the fuel oil pump



After the pump, there is a relief valve to relieve any excess pressure if an isolation valve is closed or if the burner is not calling for all the capacity of the pump. A gear pump is a positive displacement pump.

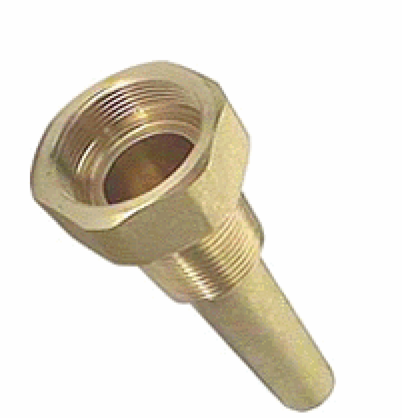
Adjustable pressure Oil Relief Valve

Immediately after the relief valve is a check valve to prevent the oil from flowing backward when the pump is shut down.

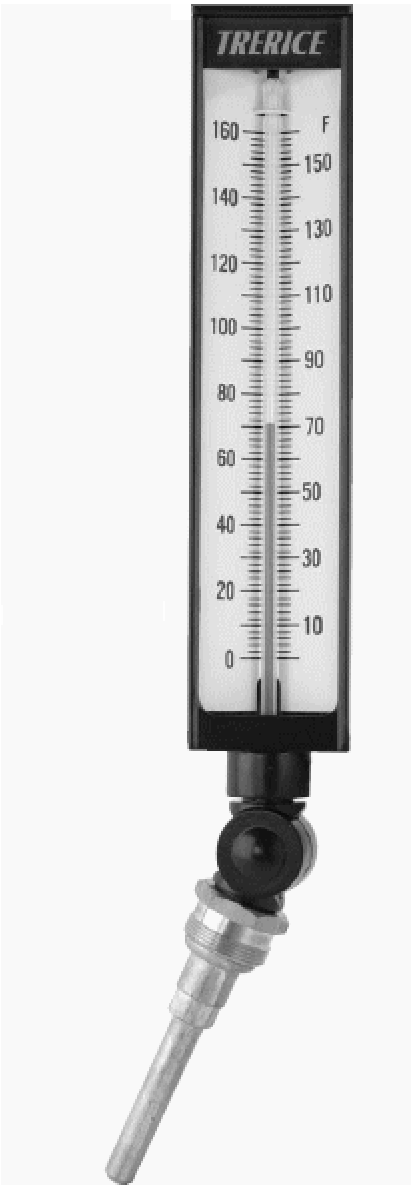


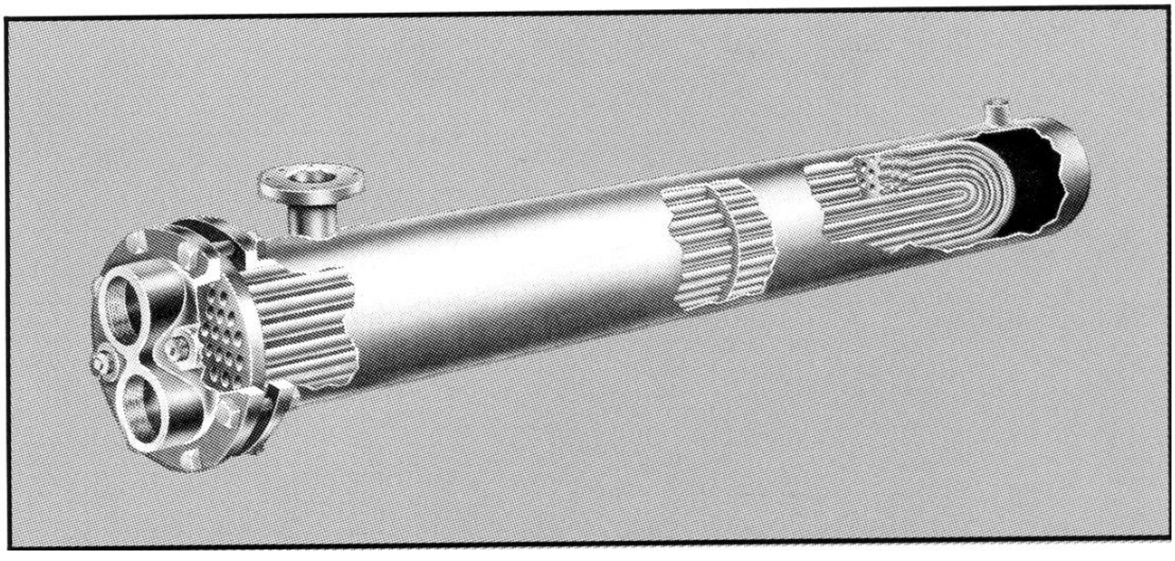
Once the oil passes through the check valve, it passes a thermometer in a thermometer well on its way to the fuel oil heater.

Thermally Conductive Paste



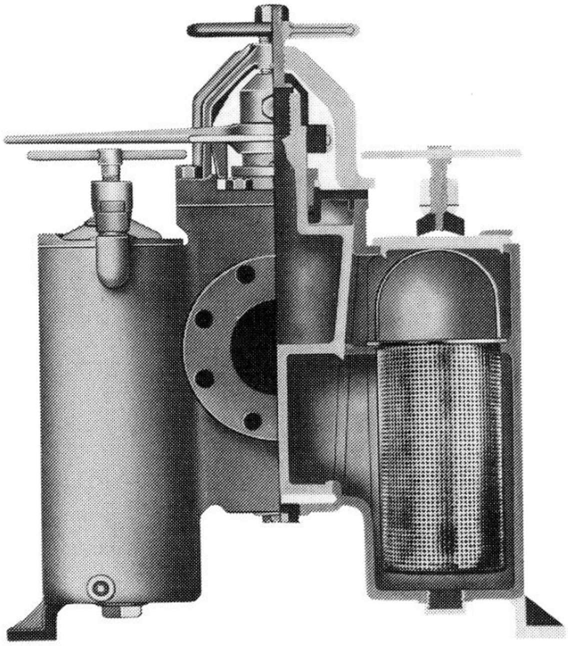
A thermometer well allows a thermometer to be removed without shutting down the system to replace a bad thermometer. A special thermal conductive grease or paste is in the well to allow accurate readings





Steam heated fuel oil heater

After the oil heater the oil goes through a duplex strainer with a fine mesh. The holes in the fine mesh are small enough to prevent anything large enough to clog the burner tips.

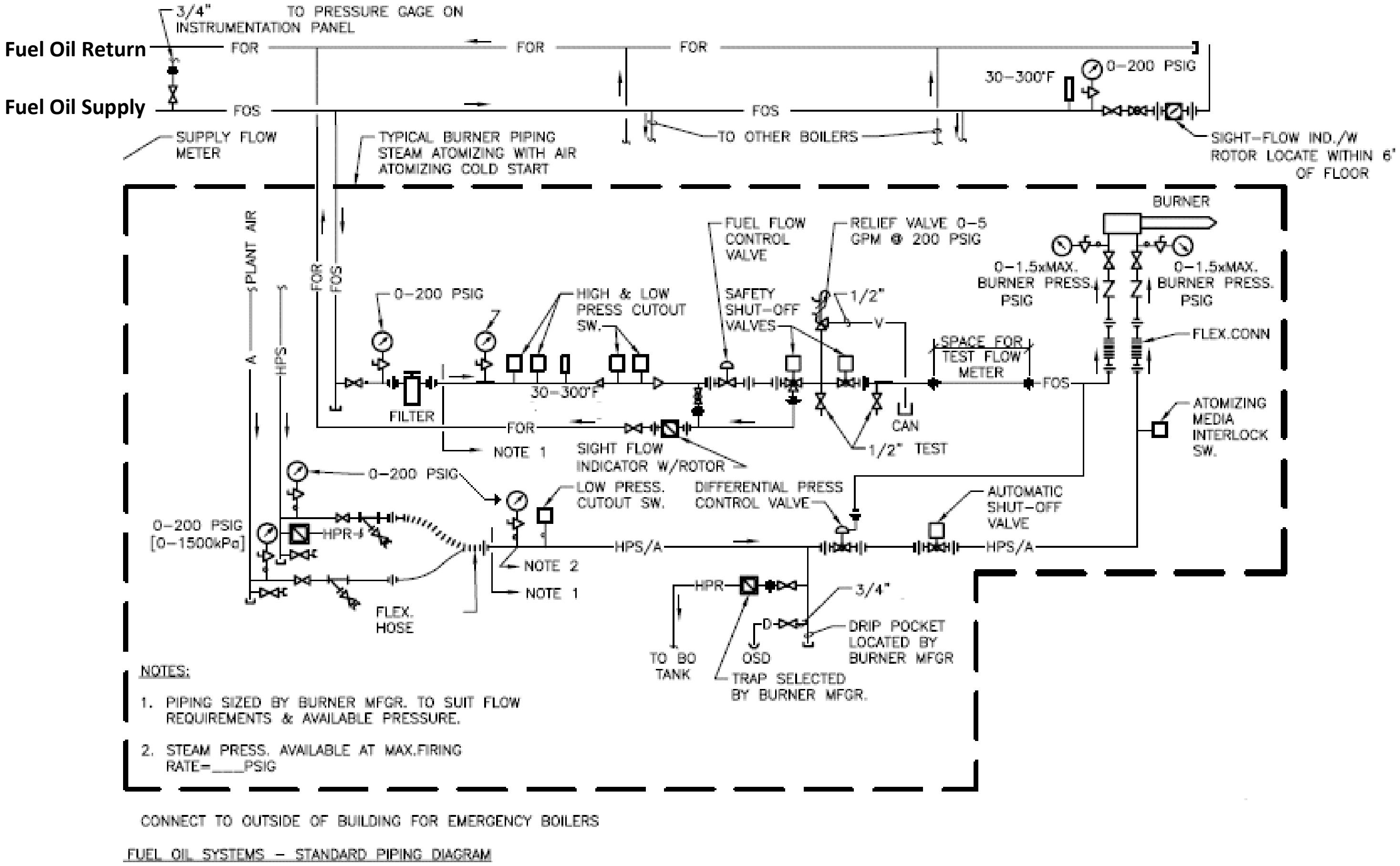


Teed into the discharge line is a Fuel Oil Back Pressure Control Valve that will return any excess pressure from the fuel oil pump supply to the return line. It operates at a lower pressure than the relief valve.

Oil meters are on the supply line and return line. The supply minus the return is the actual oil used.

Fuel Oil Back Pressure Control Valve

Oil Train Diagram Part 2

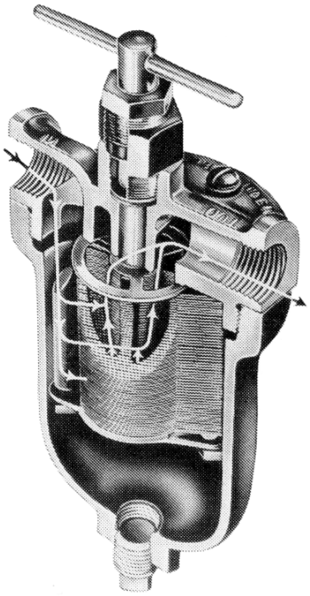

Fuel Oil Return
Fuel Oil Supply
3/4"
TO PRESSURE GAGE ON INSTRUMENTATION PANEL
FOR
FOR
FOR
FOS
FOS
30–300°F
0–200 PSIG
SUPPLY FLOW METER
TYPICAL BURNER PIPING STEAM ATOMIZING WITH AIR ATOMIZING COLD START
TO OTHER BOILERS
SIGHT–FLOW IND./W ROTOR LOCATE WITHIN 6' OF FLOOR
BURNER
PLANT AIR
FOR
FOS
A
HPS
FUEL FLOW CONTROL VALVE
RELIEF VALVE 0–5 GPM @ 200 PSIG
0–1.5xMAX. BURNER PRESS. PSIG
0–1.5xMAX. BURNER PRESS. PSIG
0–200 PSIG
HIGH & LOW PRESS CUTOUT SW.
SAFETY SHUT–OFF VALVES
1/2"
V
SPACE FOR TEST FLOW METER
FLEX.CONN
FOS
FILTER
30–300°F
CAN
FOR
NOTE 1
SIGHT FLOW INDICATOR W/ROTOR
1/2" TEST
ATOMIZING MEDIA INTERLOCK SW.
0–200 PSIG
LOW PRESS. CUTOUT SW.
DIFFERENTIAL PRESS CONTROL VALVE
AUTOMATIC SHUT–OFF VALVE
0–200 PSIG [0–1500kPa]
HPR
HPS/A
HPS/A
NOTE 2
NOTE 1
FLEX. HOSE
HPR
3/4"
D
DRIP POCKET LOCATED BY BURNER MFGR
TO BO TANK
OSD
TRAP SELECTED BY BURNER MFGR.
NOTES:
1. PIPING SIZED BY BURNER MFGR. TO SUIT FLOW REQUIREMENTS & AVAILABLE PRESSURE.
2. STEAM PRESS. AVAILABLE AT MAX.FIRING RATE=____PSIG
CONNECT TO OUTSIDE OF BUILDING FOR EMERGENCY BOILERS
FUEL OIL SYSTEMS – STANDARD PIPING DIAGRAM

As the oil supply line enters on the left of the continuation of the diagram, there is a tee for a panel mount 0-200 pressure gauge for the front of the boiler control panel.

Panel Mounted 0-200 psi gauge

The sight flow indicator shows the flow by spinning the wheel

The oil then goes through a filter element with 0-200 pressure gauges on either side



After the filter element there are high and low pressure cut-out switches attached to the supply oil piping.

High oil pressure Cut-out

Low oil pressure Cut-out

From there it goes through a fuel oil control valve

Hauck Oil Control Valve

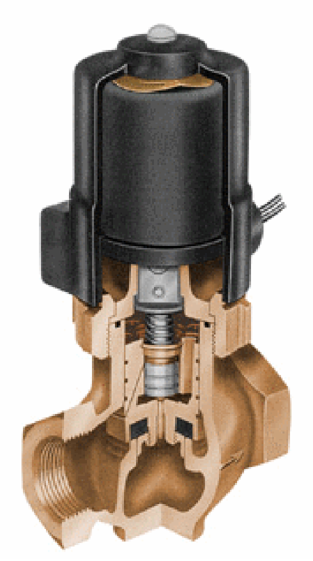
The Honeywell Modutrol Motor will hook to the linkage and control the fuel flow in relation to demand

And then through 2 oil safety shut off valves in series

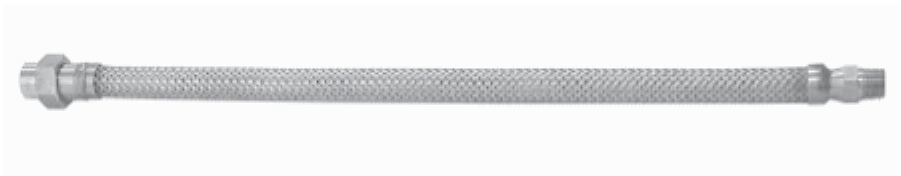
The oil line has a tap that goes to the air or steam atomizing control valve. It modulates the atomizing steam in coordination with the oil flow.

The next valve in the steam line is a safety shut off valve

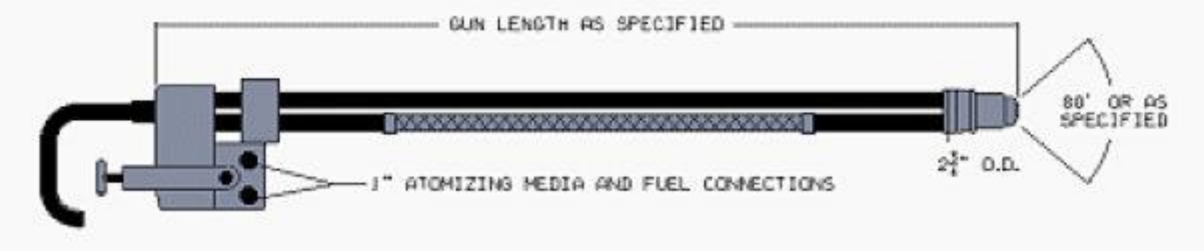
APPLICATION:
TO CONTROL THE FLOW OF STEAM. Steam must be free of sediment. Valve operates from zero to maximum differential pressure indicated in table. Valve must be mounted in horizontal pipe with solenoid enclosure vertical and on top.

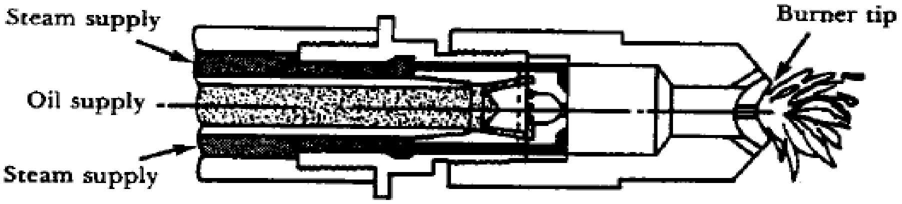


Then through a flexible stainless steel hose connection with a check valve

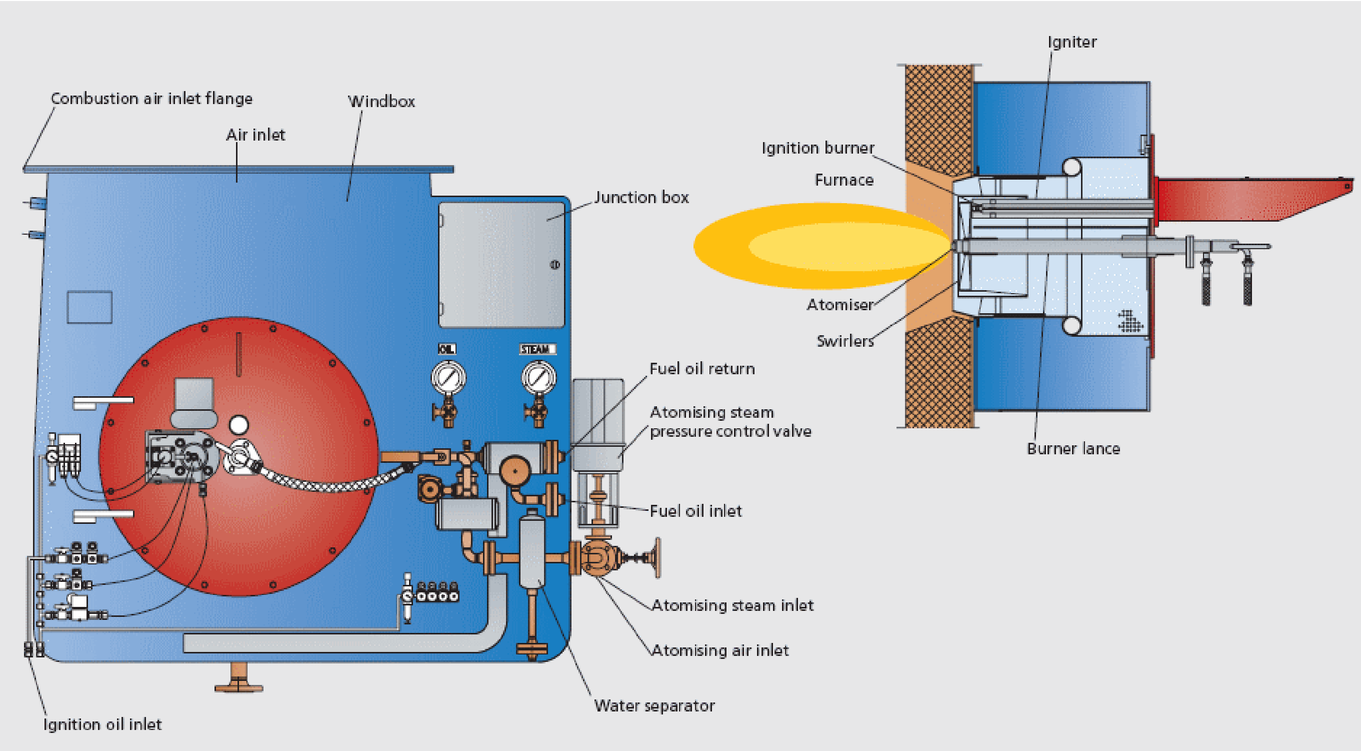


And finally you get to the steam atomized oil burner





Internal mix steam atomizing burner used for oil firing.



Steam Atomized burner front

Explain the process of mechanical atomization.

Oil is atomized by the use of pressurized oil forced to flow at high velocity through small passages in the sprayer plate, before it enters the burner tip chamber tangentially. This causes the oil to rotate at a high rate of speed before entering the burner tip orifice. As it leaves the orifice the oil is in the form of a fine cone shaped mist. The spray from the burner does not rotate although the flame does. This is accomplished by the admission of air through the air register at an angle to the spray.

Detroit Edison Steam Course Fuels and Combustion page 16

Explain how to adjust a mechanical atomizer for a varying load change.

The fuel burning rate is controlled by oil pressure and size of orifice in the tip. An increase in oil pressure leads to an increase in the amount and velocity of oil leaving the burner tip. Changes in burning rate should be accompanied by a change in the amount of combustion air admitted and often must be accompanied by a change in the air damper position. Care should be taken to increase the air flow first before increasing the oil flow. When reducing load, the oil flow should be reduced first, followed by a reduction in air flow.

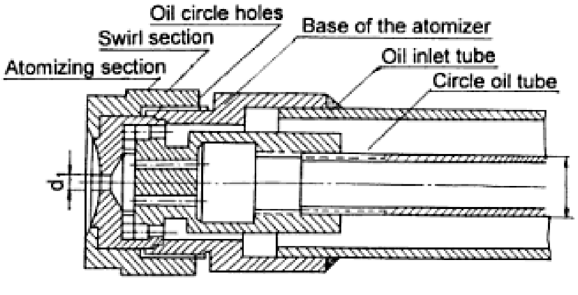
Detroit Edison Steam Course Fuels and Combustion page 16

What would be the turn-down ratio on a typical mechanical atomizing type oil burner?

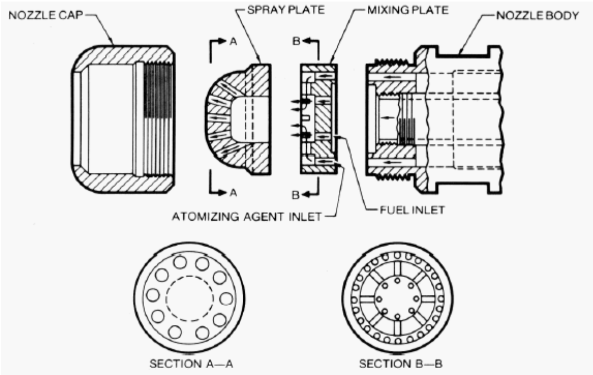
The oil pressure at the entrance to the tip orifice determines the amount of oil that can be forced through it. Reduction in viscosity depends on the characteristics of the oil, as well as capacity of the oil heater. Therefore the operating range of a given atomizer tip orifice is limited to approximately1 ½ to 1, with an oil pressure change of as much as 200 psi.

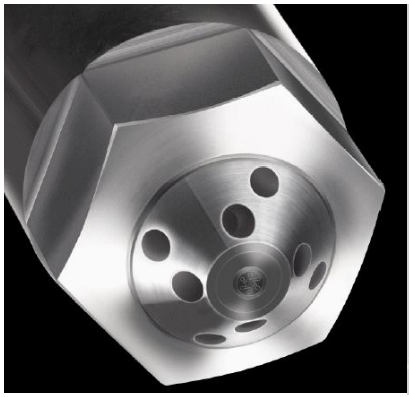
Note: A Peabody Wide Range Burner with oil recirculation has an operating range of 10 to 1.

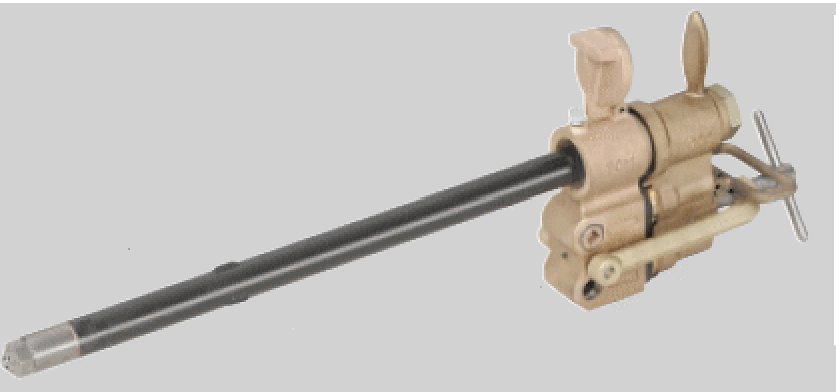
Blue Combustion Engineering page 10·12



Cross section view of a return oil inner circle type atomizer







What happens to the oil that isn't used by the burner?

The excess oil not used by the burner is sent back to the storage tank via the return line. The amount of excess oil going back to storage is regulated by the oil recirculating valve.

Some oil pumps have a spring-loaded by-pass valve which discharges the excess oil to the pump suction or then storage tank. This by-pass valve is set to maintain the desired pressure at the burners, and since the pump has a capacity in excess of the burner requirements it is possible to supply the demand automatically.

Steam Plant Operation by Woodruff and Lammers 8th edition page 308

On a steam atomizing burner, which psi is higher, the steam or the oil?

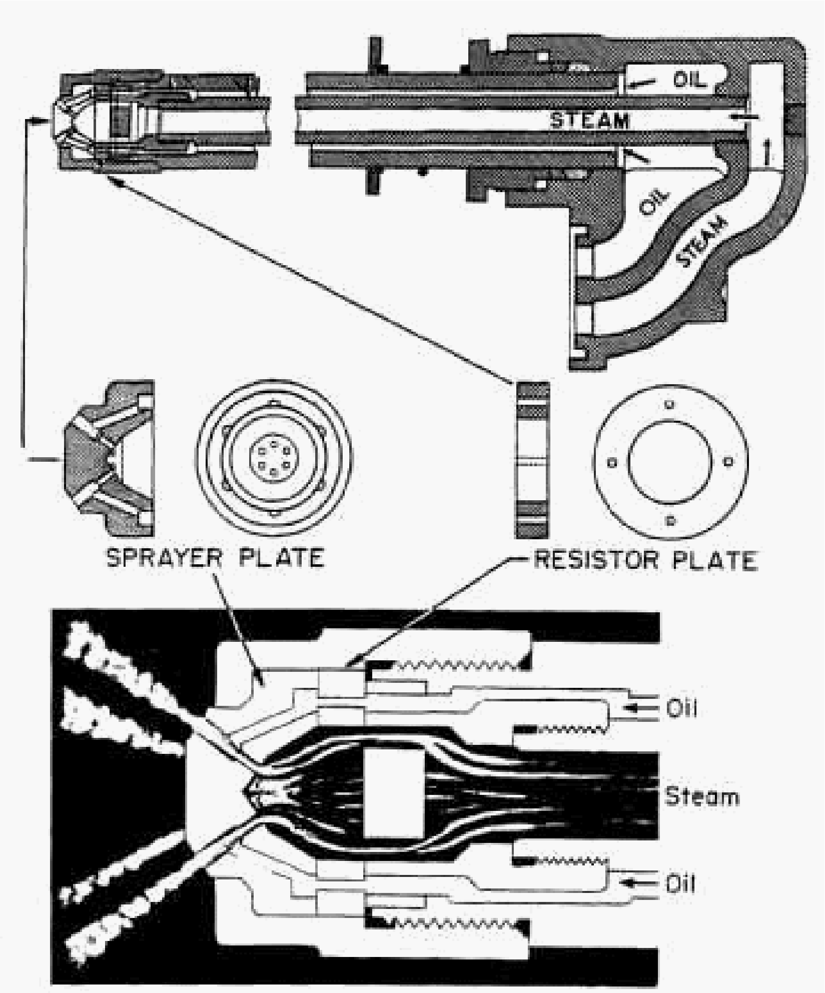
The steam pressure

On the light fuel oil (#2) igniters at Mistersky, the air atomizing pressure is 80 psi which is higher than the oil pressure which is 60 psi.

Mistersky - Operations Manual #6 Boiler

Steam for atomization should be at a pressure of 75 to 150 psig. The temperature of the oil delivered to the burner is at a pressure of 10 to 15 psig and at 150 to 190 degrees F.

Kent's 12th page 7-72

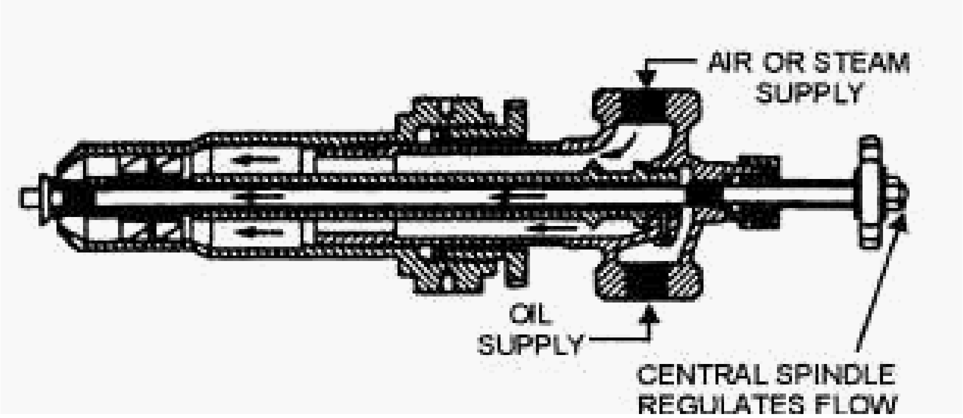


With a steam atomizing burner which medium do you lead with, upon start-up and load changes?

On start-up the steam valve is first open to blow out any accumulation of water. Next the oil valve is slowly opened and the spray is ignited by a torch.

On increased load changes lead with steam, otherwise particles of burning oil will drop to the floor.

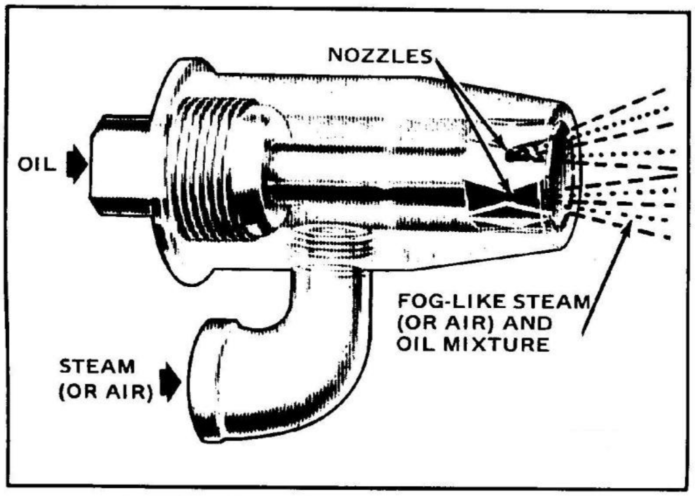
Oil & Gas Burning - International Text Book Company page 69



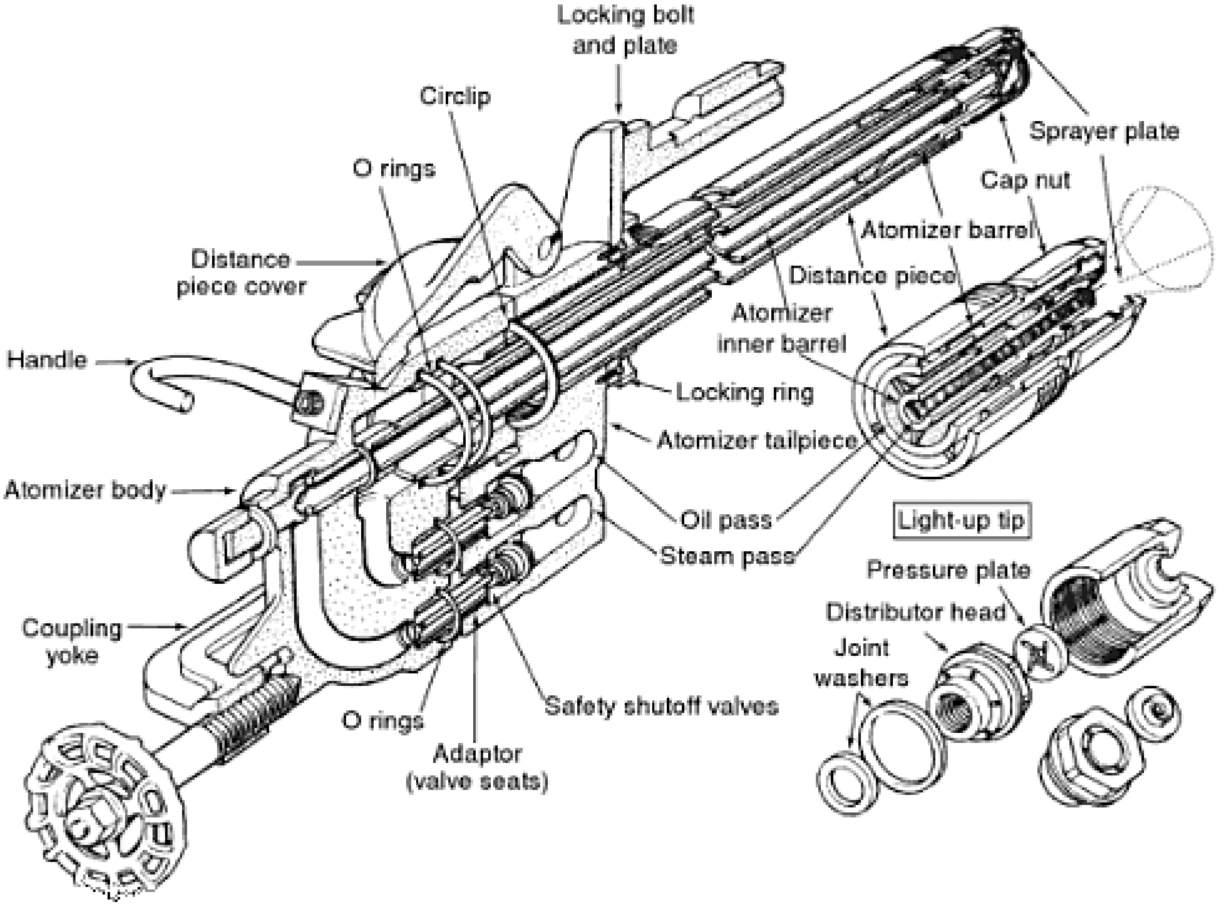
On a steam atomizing oil burner system, name the pressure ranges for oil and steam.

The burning rate can be varied from 500 to 3,500 lb. of fuel per hour without changing the spray plate and with pressure variation of 75 to 150 psi in the steam supply and 100 to 140 psi in the oil supply. With careful operation, the steam required for atomization does not exceed 1 percent of the quantity generated by the boiler.

Kent's 12th. edition page 7-72



TYPICAL INSIDE-MIXING, HIGH PRESSURE AIR- OR STEAM-ATOMIZING OIL BURNER.



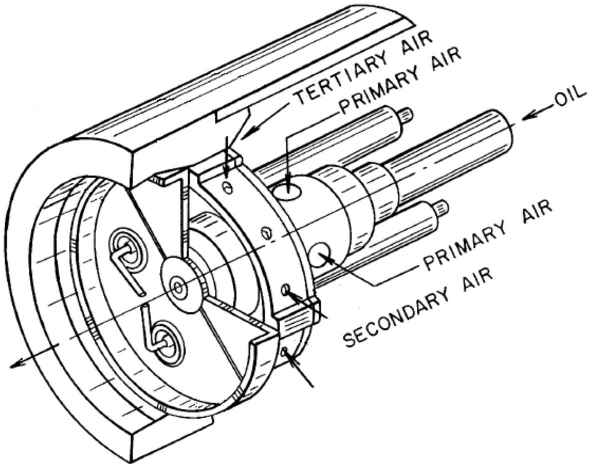
Assembly and parts of typical steam jet atomizer.

Describe how steam atomized, air atomized, and mechanically atomized fuel oil burners operate.

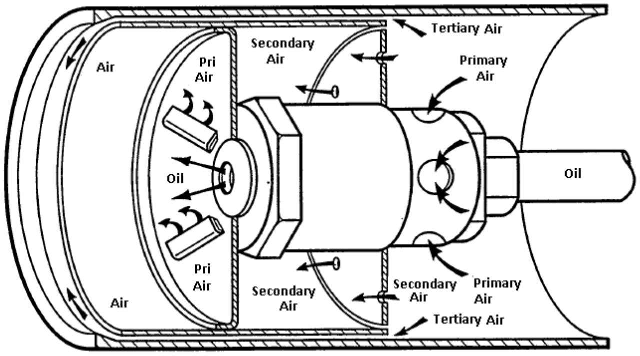
Steam atomizing burners range in size from 80 gal/hr., using grade #2 and heavier oils, mostly for boilers. Atomization occurs due to the impact and expansion of steam. Oil and steam flow in separate channels through the burner gun to the burner nozzle where they mix before discharging through an orifice into the combustion space. The spray of atomized oil and steam forms a hollow cone. A forced draft fan supplies the combustion air which passes through the direction vanes of the burner register, through the burner throat, and into the combustion space. The vanes give the air a spinning motion. The burner throat directs it into the cone shaped oil spray for an intimate mixing of air and oil. Full load oil pressure at the burner inlet is generally some 100 to 150 psig. Steam pressure usually is kept higher than the oil pressure by about 25 psig. Load range is accomplished by varying these pressures. Some designs operate with oil pressure ranging from 150 psig at full load to 10 psig at minimum load, resulting in a range of turn down of some 8 to 1, making steam atomizing burners nicely suited to modulating control. Depending on burner design, the amount of steam used for atomizing the oil range from .5 to 3% of the steam compressed air from the plant air supply may be used for atomizing. Some designs permit use of a pressure atomizing nozzle tip for start up when neither steam nor air is available. When properly adjusted, steam atomizing burners operate well with 15% excess air, 14% CO_2, at full load without visible smoke and with not more than a trace of CO in the flue gas. They use from 1 to 5 pounds of steam to atomize a gallon of oil, depending upon the burner design.

I.U.O.E. Fuels, Oils and Lubricants page 6-2-27-32

Air atomizing oil burners range in size from .5 to 530 gallons per hour using grades #2 and heavier, mostly for boilers and warm air furnaces. The air atomizing burner is similar to the pressure atomizing, except for the nozzle. Atomizing air from a pressure blower or a compressor is injected into the oil to aid atomization and to help carry the atomized oil through the nozzle orifice to form a hollow cone of oil spray inside the furnace. This burner has a wide load range, or turndown without changing nozzles: 3 to 1 for smaller sizes and up to 6 or 8 to 1 for larger sizes. Load range is achieved by simultaneously varying the oil pressure, the atomizing air pressure and the combustion air entering the burner. Some designs of this burner use relatively low atomizing air pressure of 5 psig and lower; other designs use air pressure up to 75 psig. The burner uses from 2 to 7 cubic feet of compressed air per gallon of fuel oil. When properly adjusted, air atomizing burners operate well with 15 to 25% excess air, approximately 14 to 12% CO_2, at full load with no visible smoke and with no more than a trace of CO in the flue gas.



Air Atomized Oil Burner



Air Atomized Oil Burner

Mechanical atomizing oil burners range in size from 80 gal/hr. using fuel oil grades #2 through #6 for boilers and industrial furnaces. Oil pressures used are some 90 to 900 psig. Load ranges are obtained by varying the pressure between these limits.

I.U.O.E. Fuels, Oils and Lubricants

In these burners, the oil is atomized by using relatively high pressure on the oil and forcing it to flow at high velocity through small passages in the sprayer plate, before it enters the burner tip chamber tangentially. This causes the oil to rotate at high speed within the chamber before being passed through the burner tip orifice. As it leaves the orifice, the oil is a mist in the shape of a cone. The fuel burning rate is controlled by oil pressure and size of orifice in the tip.

Detroit Edison Steam Course, Fuel Burning Equipment

What is the air pressure range when using air for the atomization of oil?

20 lbs. to 30 lbs. above fuel oil or steam (atomizing medium is always higher than fuel).

Joe Grubb

What do you do if you do not have a auxiliary steam for steam atomizing oil guns?

Use air atomization to bring your boiler up and then switch to steam. If no air or steam is available increase your oil pressure and fire the burners mechanically.

Joe Grubb

Explain oil burner ratio.

Oil burner ratio is the difference in lbs or gallons that a particular oil burner can produce between high output and low output.

Below the minimum output the burner would drool and any above the maximum output no more oil could physically pass through the burner tip.

Proportion: Turn down ratio: Ratio of maximum to minimum fuel input rates.

Name the pressure ranges for a low and a high pressure air atomizing burner.

Low psi - 2 - 10 inches water gauge   High psi - 20 - 30 psig

Kent's 12th edition page 2-51
Detroit Edison Steam Course Fuels and Combustion

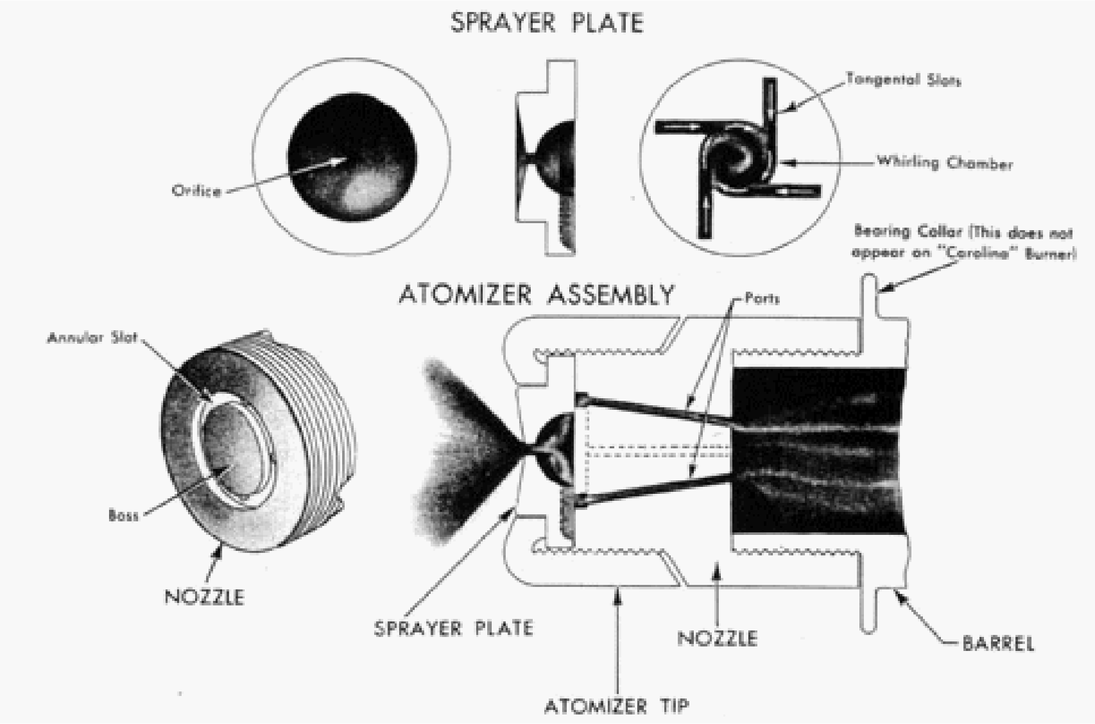
What is the atomizing pressure on a high pressure air or steam atomizing oil burner?

The pressure ranges between 25 and 150 psi.

Honeywell Flame Safeguard Controls page 20

What do the numbers and letters symbolize on an oil burner tip?

Drill size, ratio of drill size to the total area of the tangential slots, and angle of spray.

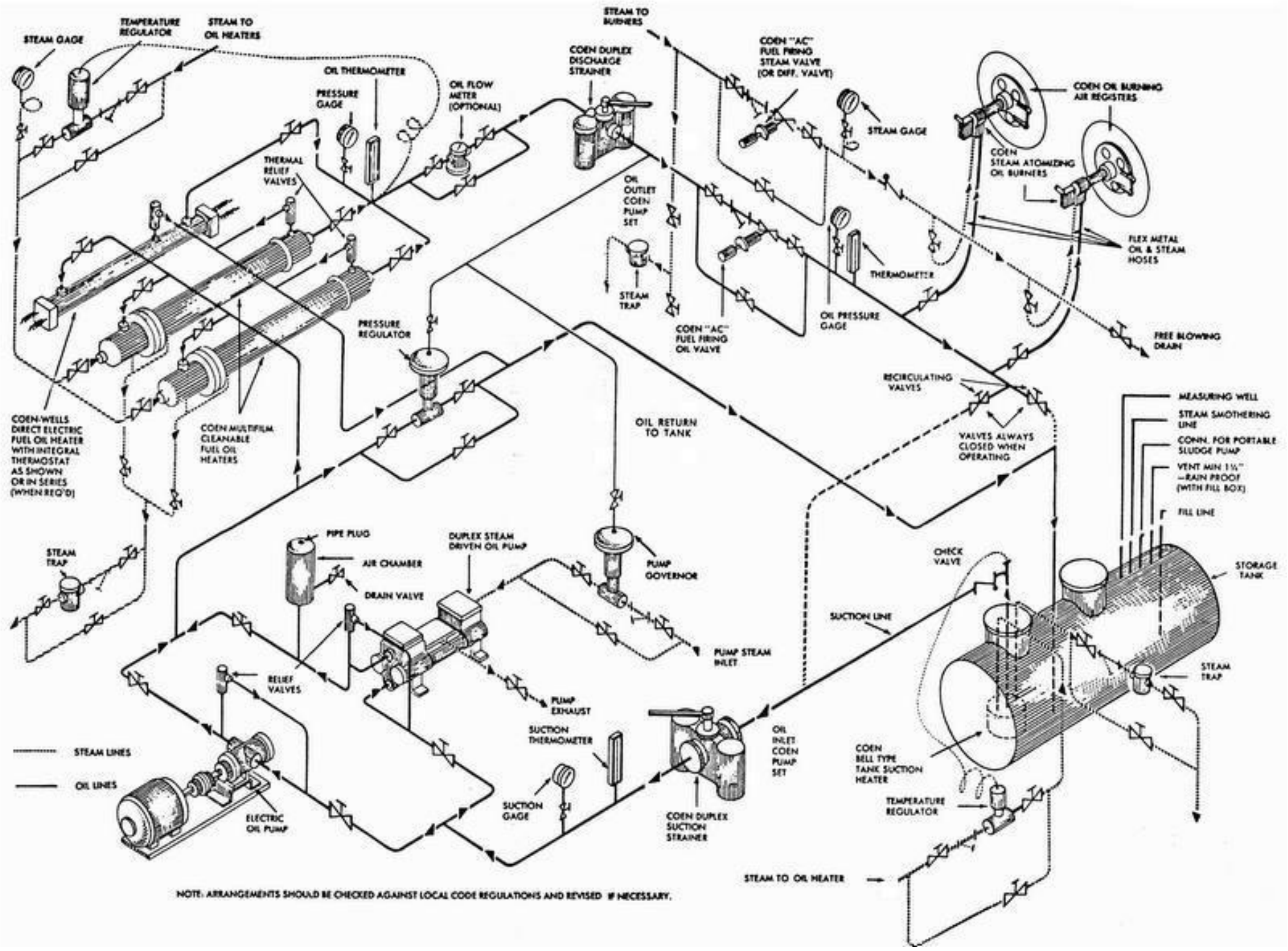


Explain a #6 fuel oil system from outside the tank to the burner.

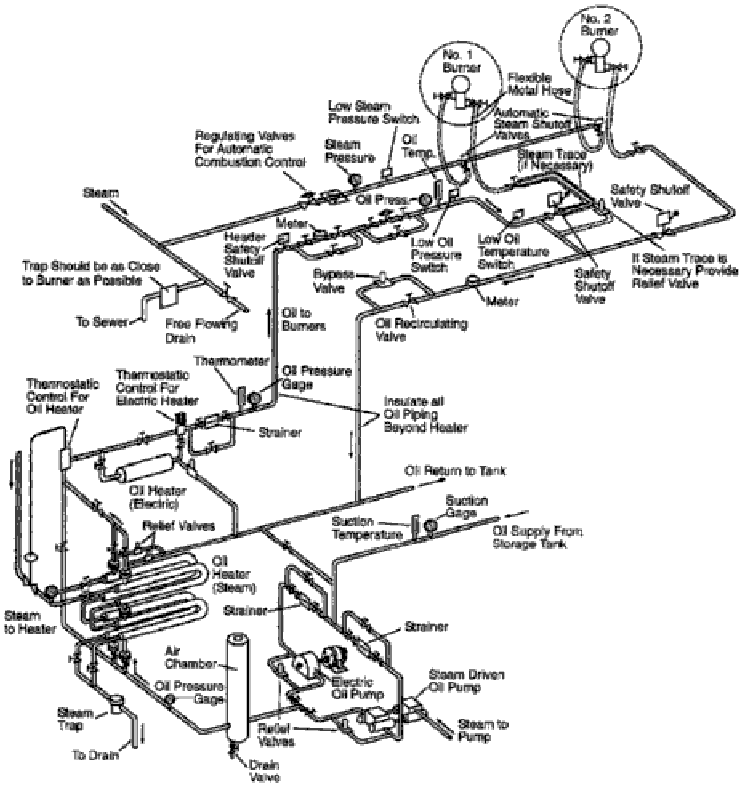
Oil is heated to 110 degrees F. in the storage tank with steam coils to lower its viscosity in order to facilitate pumping. Oil flows from the tank through a twin type suction strainer, which enables the operator to clean one screen basket while oil is passing through the other. The suction strainer is of the coarse type 16 - 10 mesh. Oil then flows to a set of pumps, which may be steam or electric driven. Duplex and gear pumps are frequently used for pumping oil. The oil pumps are fitted with relief valves which discharge oil back to the pump suction or to the storage tank upon over-pressure.

Oil then flows to a set of heaters which are either steam or electric. They heat the oil to lower its viscosity so that it can be atomized effectively by the burners. They are equipped with relief valves which discharge to the return line in case of overpressure. Next the oil flows to the twin type fine mesh discharge strainers which are 40 to 60 mesh. Then the oil flows through a meter and to the regulating valve which sends the oil to the burners and the excess to the storage tank via the return line. Thermometers and pressure gauges in the lines permit the operator to verify the equipment's performance.

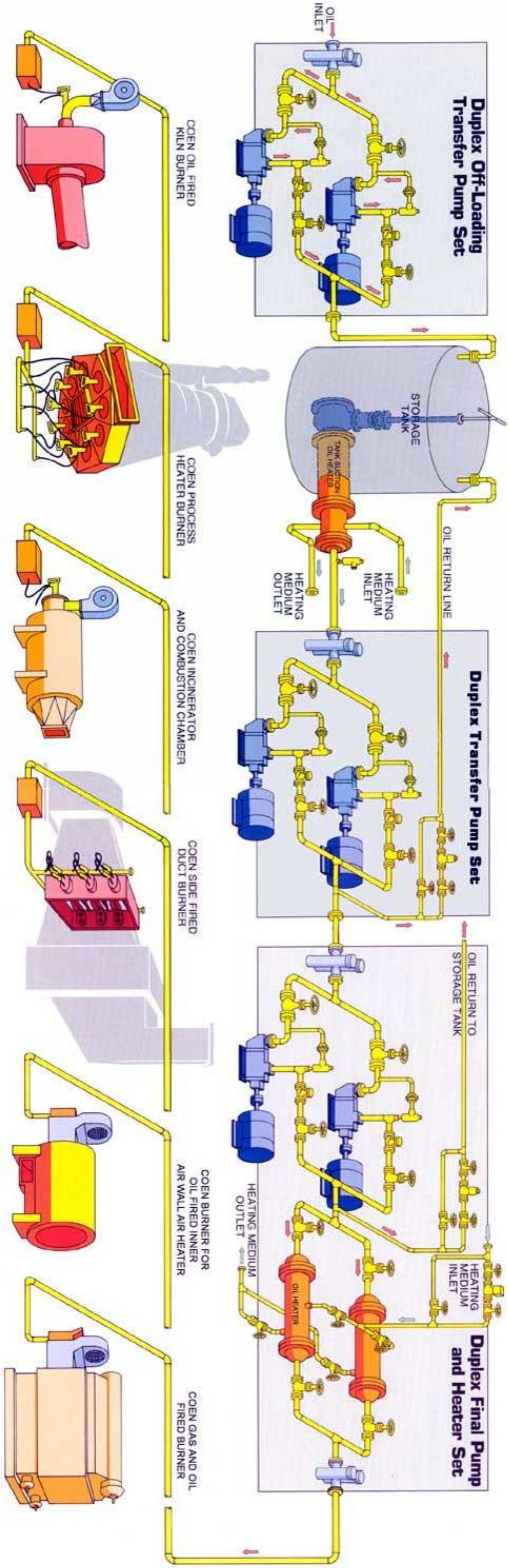
Steam Plant Operation by Woodruff and Lammers 4th edition page 197-198



NOTE: ARRANGEMENTS SHOULD BE CHECKED AGAINST LOCAL CODE REGULATIONS AND REVISED IF NECESSARY.

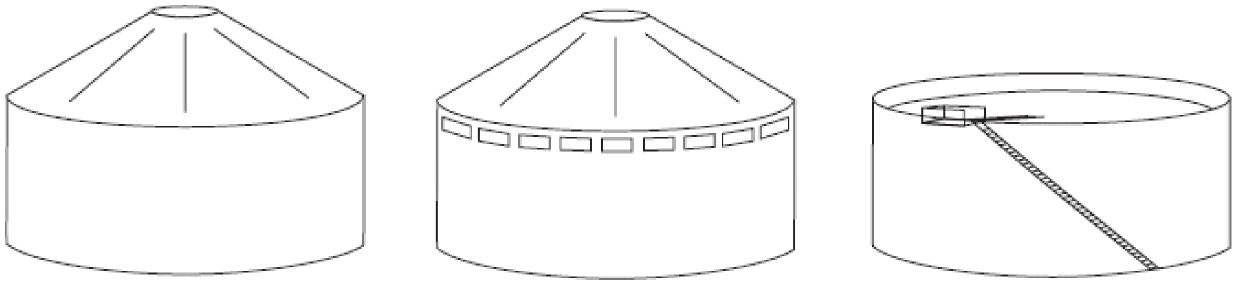


I cleaned them oil strainers like you wanted, Boss.


OIL INLET
Duplex Off-Loading Transfer Pump Set
STORAGE TANK
TANK SUCTION OIL HEATER
HEATING MEDIUM INLET
HEATING MEDIUM OUTLET
OIL RETURN LINE
Duplex Transfer Pump Set
OIL RETURN TO STORAGE TANK
HEATING MEDIUM INLET
HEATING MEDIUM OUTLET
OIL HEATER
Duplex Final Pump and Heater Set
COEN OIL FIRED KILN BURNER
COEN PROCESS HEATER BURNER
COEN INCINERATOR AND COMBUSTION CHAMBER
COEN SIDE FIRED DUCT BURNER
COEN BURNER FOR OIL FIRED INNER AIR WALL AIR HEATER
COEN GAS AND OIL FIRED BURNER

How do you heat #6 fuel oil , in large storage tanks, to pumping temperatures. Maintaining an entire tank of fuel oil at pumping temperatures is very costly. In many applications it is not practical or economical because the tanks are located underground or are not insulated. Type SHO Suction Oil Heaters are a cost-effective solution to this problem. Suction heaters are specifically designed to heat only that amount of material that is to be pumped from a large storage tank. The outlet nozzle is attached to the pump suction. The heater heats the material inside the heater pipe body which is then drawn through the heater into the suction side of the pump. This technique saves substantial energy costs since it is not necessary to heat the entire contents of the tank to draw off relatively small amounts of viscous materials. Complete weather-proof construction makes these heaters perfect for installation in large outdoor storage tanks. Large heater inlet provides smooth, full-flow through the heater. http://www.omega.com/HEATERS/pdf/SHO_HEATER.pdf

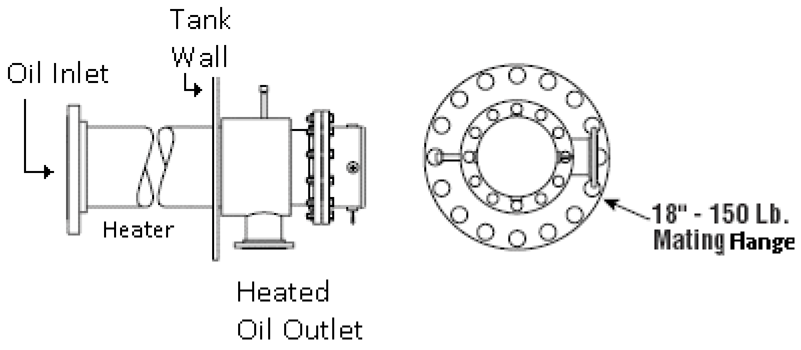
FUEL STORAGE TANKS- Basic Configurations

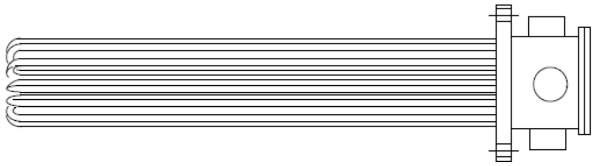


Cone Roof Tank

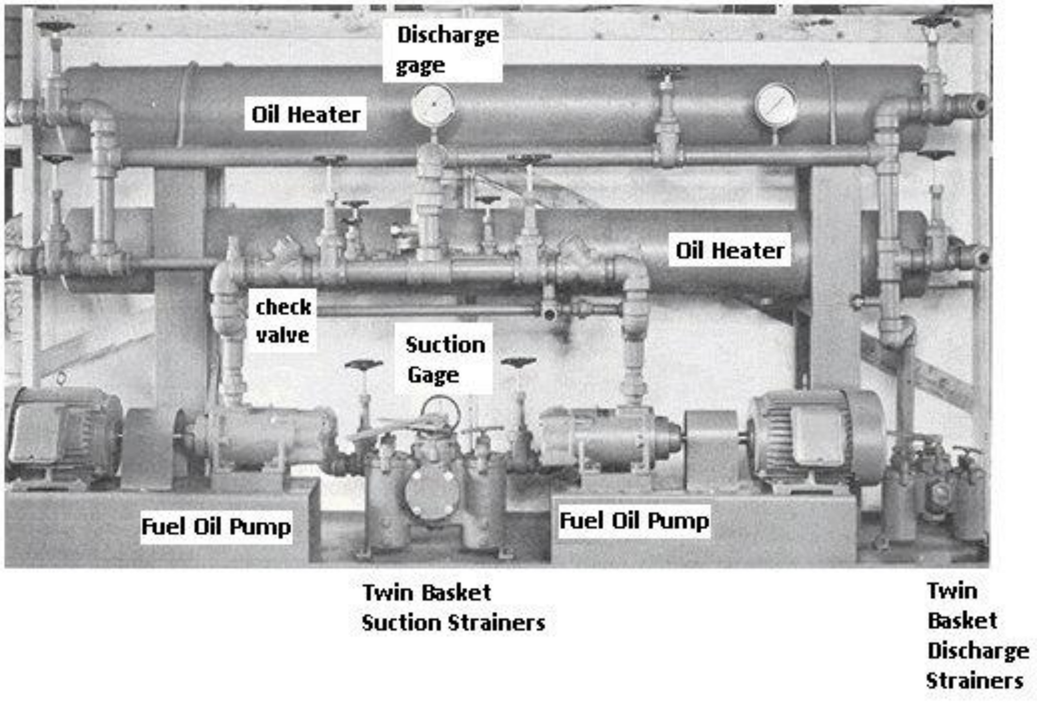
Covered Floating Roof Tank

Open Floating Roof Tank





Heating Element



Two (2) Dusenbery Engineering Company Model 25HDD-225 Duplex Pumping, Heating and Straining Sets, 25GPM nominal capacity. Each pump is capable of 30 GPM on #2 oil and 36 GPM on #6 oil, 225 psig discharge pressure. Heater is capable of 25 GPM on #6 fuel oil from 100-200° F. using 660#/hr., 100psig saturated steam. Complete with (2) fuel oil heaters, ASME stamped, thermal relief valves, steam traps with strainer and 3-valve bypass; (2) rotary screw rotary fuel oil pumps directly connected to 10HP, 1800 RPM, TEFC motors with relief valves and motor starter; (1) duplex suction strainer; (1) automatic oil pressure regulator with 3-valve bypass; (1) steam trap with 3-valve bypass; (4) line mounted pressure gauges and (2) line mounted thermometers. Sets are completely piped and wired, and all equipment is mounted on a drip pan and structural base, also known as a skid.

How many times bigger than the area of the pipe size should the area of the holes for the fuel oil strainer be?

The area of strainer mesh should be at least twice the area of the pump suction. The size of the holes should be smaller than the hole in the burner tip.

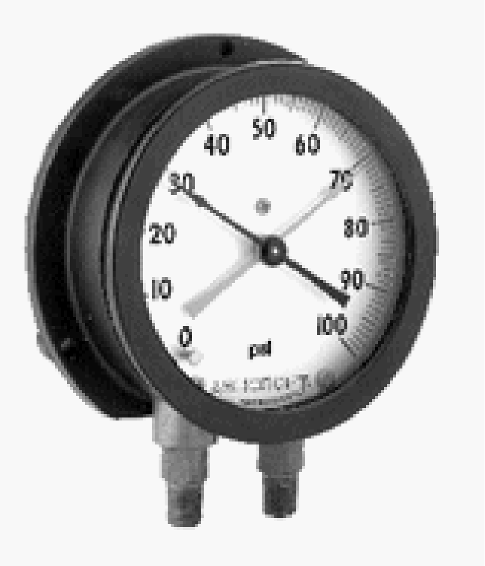
Grubb notes

What type of gage is on an oil train and how can you tell if the oil is flowing?

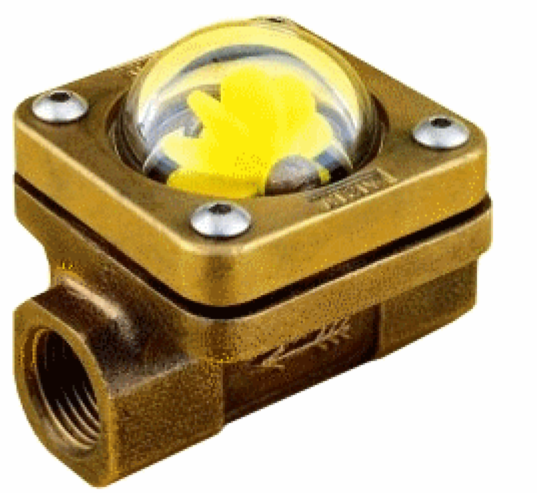
A duplex gauge is used on the suction side of the transfer pumps. If oil is flowing there will be a pressure differential across the suction and discharge gauges.

If a flowmeter is installed, check the flowmeter.

Mistersky - Operator



As the discharge strainer gets dirty, there is a greater differential between needles



The yellow spinner indicates flow

What type of protection is provided on a oil system?

a. Fire protection at the storage tanks, foam, water or steam.

b. Dikes surrounding oil tanks to contain spills.

c. Remote operated shut-off valves at storage tanks.

d. Suction and discharge strainers to protect equipment.

e. Pressure relief valves on pumps.

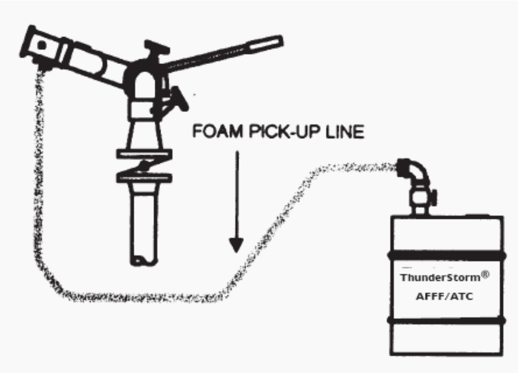
f. Temperature relief valves on heaters.

g. Fusible links on supply lines.

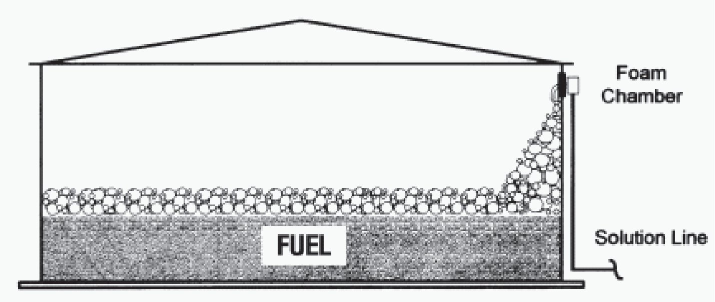
h. High and Low pressure cutouts.

i. High and Low temperature cutouts.

Joe Grubb



Foam spray in case of fire



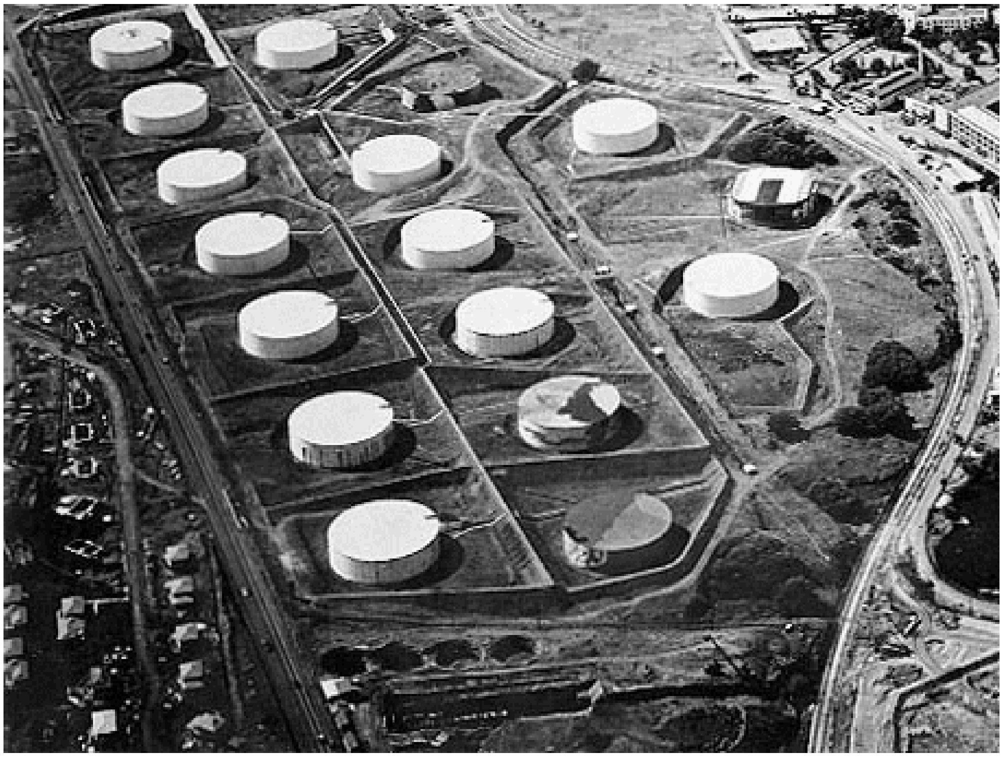
The foam nozzle inside will release its foam from the foam chamber in case of fire and spread over the flames, choking off the oxygen and putting out the fire

What type of protection or safety devices are found on an oil tank?

A steam smothering line to the oil storage tank is installed for the purpose of fire protection. In the event of fire in the storage tanks, steam is admitted to the tanks to expel the oxygen. There is also a fusible fire link in both the supply and return line, just inside the plant, to protect the plant and tank in the event of an in plant fire. A dike wall is built around the perimeter of an above ground tank to contain the oil in the event of a rupture. Water guns are mounted on top of the dike wall to help fight a fire. Also cathodic protection, double wall construction, leak test well or monitors, tie downs or cement cover (inground), and vent is 5 times the area of the inlet.

Detroit Edison Steam Course Fuels and Combustion page19

Containment typically consists of a dike and pad structure or a double-walled tank. The dike and pad structure for large tanks must be able to contain 125% of the capacity of the tank. http://clean-water.uwex.edu/pubs/pdf/add.storage.pdf



The oil tank farm at Pearl Harbor in 1941. The Japanese made a huge mistake in not attacking these tanks and America was able to turn the tide of battle in the Pacific in World War II at the battle of Midway because fuel was available for the Aircraft Carriers. Notice the dikes that prevent one storage tank on fire from spreading to another tank.

Oil pumps and burners should be protected by strainers. Strainers should be selected with orifices that are smaller than the drillings in the burner tips to prevent possible plugging.

ASME Section VII 1992 Code Subsection C3.241

How is sludge removed from a filter or strainer?

Fuel Oil Strainers: Remove, soak in kerosene, and manually brush. Flush and wash.

Betz 6th Edition page 123

How is sludge removed from an oil tank?

Sludge is a mixture of organic compounds that have precipitated after different oils have been blended. The most notable is the asphaltene group, consisting of heavy hydrocarbons. Asphaltene and waxes are not detectable with normal test methods because the solvents used, (benzol and toluene) dissolve them. The presence of these compounds usually is not detectable until they cause problems.

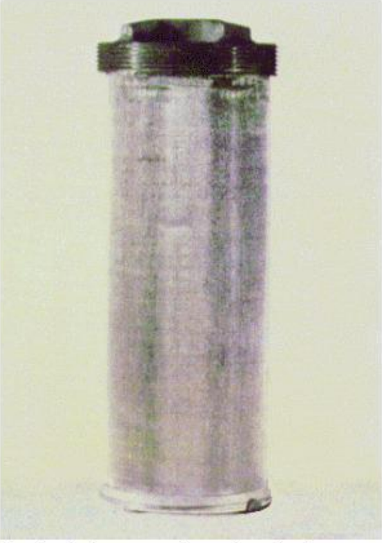
Removal is accomplished by the use of a sludge removal line and pump set. The line suction is located one inch from the bottom of the tank where sludge is drawn up and removed. Also a solvent can be used to dissolve the sludge and therefore be allowed to pass to the burner but this method is seldom used in a fuel oil system. A bottom sample spigot is used to detect sludge.

Power Plant Engineering page 3.53

The Problem: Clean 8 inch depth of sludge from a 55,000 gallon underground concrete No. 6 oil storage tank belonging to Heppenstall Steel of Pittsburgh, Pa. in 1954.

The Prescription: Introduced 3 drums of *Alken Even-Flo 905* on top of the sludge and a quantity of No. 6 oil equivalent to the amount of sludge present. Agitated with air for 2 days (heating would have improved the speed of results, but heat was not an option for this client). Pumped down all that was possible and again added 3 drums of *Alken Even-Flo 905* and agitated again for 2 days.

Typical dirty strainer that is the result of using untreated fuel.



Typical clean strainer that is the result of using Even-Flo® in the fuel.

How do you tell when fuel oil strainers need cleaning?

It is recommended that pressure gauges be installed on the inlet and outlet of the strainer to indicate pressure drop across the unit. In many cases the practice is to strain through one strainer until pressure loss on the line indicates that the basket needs cleaning. Once that occurs, the flow is switched through the clean basket and the dirty one is cleaned. Usually strainer cleaning occurs on a scheduled basis, depending on where you work.

I.U.O.E. Fuels, Oils and Lubricants page 6-2-75

Name the pressure drops across the fine and coarse strainers of a #6 fuel oil train.

The maximum desirable pressure drop is 2 to 3 psi across the course strainer (suction).

The desired pressure drop across the fine strainer (discharge) is 5 to 10 psi or greater.

Discharge strainers are required only if oil heating is necessary, since heating of the oil may result in some coking.

The psi drop in the equipment and piping from the pump discharge to the outlet of the discharge strainer may be as high as 25 psi without excessively penalizing the pump/drive selection.

Power Plant Engineering page 3.65

Why use coarse strainers in a oil train and not all fine?

Too fine a mesh may resist the flow of the relatively cool oil and put an excessive strain on the pump, often causing the pump to lose suction. Strainers are usually made of either wire mesh or perforated sheet metal.

The area of the openings in the strainer should be several times the cross-sectional area of the pipe in order to prevent the oil pressure from being unduly decreased.

Suction strainers are provided with gauze not finer than 8 mesh. That is gauze having 64 openings per square inch. This is sufficient to protect the pump;

Oil & Gas Burning under Boilers by International Text Book Co. pages 27-28

What determines the screen mesh on fuel oil strainers?

Strainers are provided to prevent foreign material from being delivered to the burners. It is good practice to use a coarse screen, 16 to 20 mesh in the suction line, and a finer screen, 40 to 60 mesh, in the discharge line. The discharge screen is located in the line after the oil heater.

Steam Plant Operation by Woodruff and Lammers 4th edition page 197

The size of the suction strainer is determined by what size particles can pass through the fuel oil pump without damage. This will vary with the type of fuel oil pump used. The discharge strainers screen size is determined by the particle size that the burner tip can pass without plugging.

Plenty Strainers Representative

Explain the operation of the relief valves on an oil train at Mistersky.

The relief valves on #7 unit heavy fuel oil skid pumps will open at a over-pressure of 650 psi and discharge into the return line. The heater relief valve will open at a overpressure of 680 psi and discharge into the return line.

In some installations the pump relief valve may discharge back into the pump suction.

Mistersky - Operator

What would be the results of a pump outage on an oil train?

If the fuel skid pump or the constant differential pump was lost, its back-up which is in the standby/auto mode would take over.

If any one pump and its back-up went down within the fuel train, two out of the three pumps would have sufficient capacity to keep the boiler on line.

Operator - Mistersky

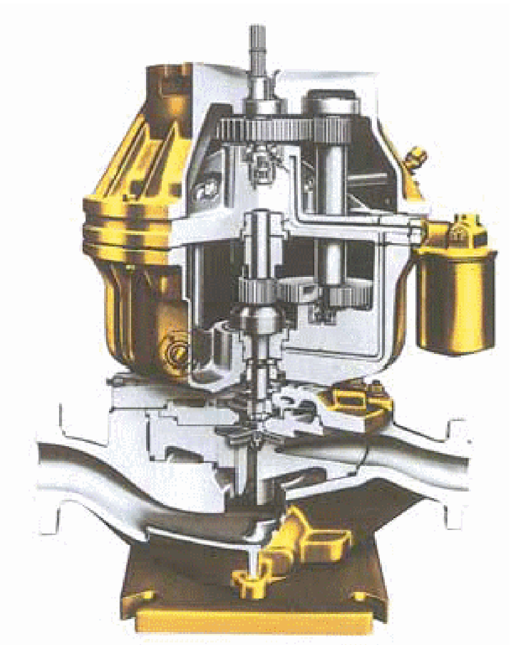
What would be the results of a transfer pump outage on a oil train?

If the forwarding house transfer pump went down, its back-up which is in the standby/auto mode would take over. If both forwarding house transfer pumps were lost, the fuel oil skid pump would have sufficient suction to draw oil from the storage tank.

If your boiler is at a high firing rate, you will have to reduce the load on the boiler.

The forwarding house transfer pump is in-between the storage tank and the fuel skid.

Operator - Mistersky



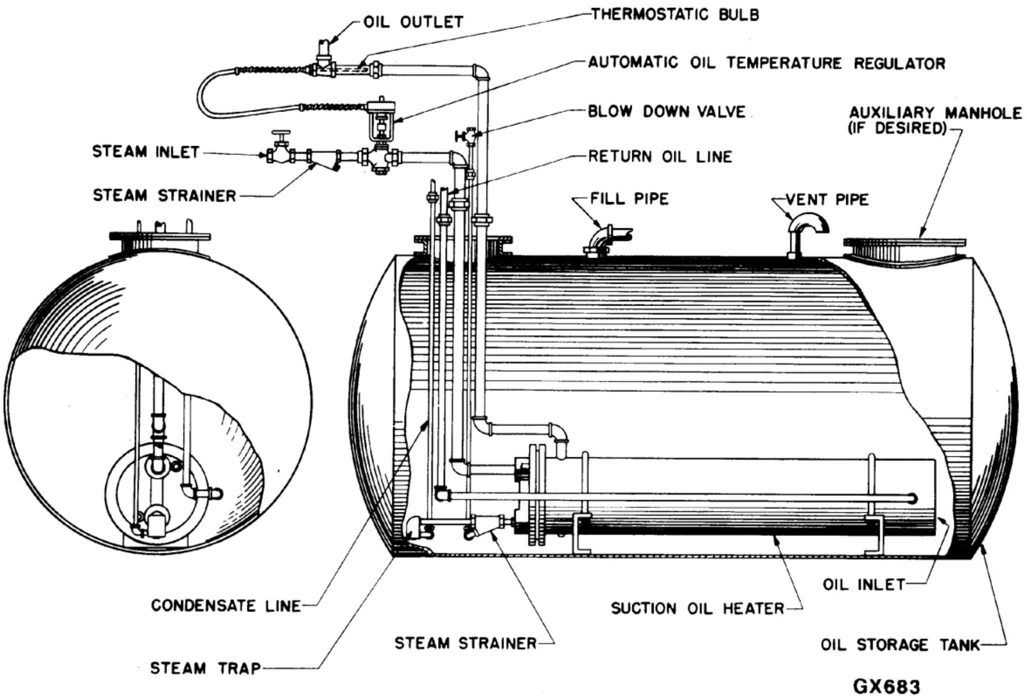
LMV-802 Pumps in Gulf Coast Refinery.

One Detroit Examiner worked at Mistersky Powerplant where they have an extensive #6 and Bunker C fuel oil system. One of his oral questions was about these Sunstrand Sundyne constant differential pumps that were between the tank farm and the burners. They kept a constant differential pressure between the suction and discharge pressures which were very high. http://www.sundyne.com/Files/Sundyne/Global/US-en/installation_&_operation_manual/SndPump-LMV-802-IOM.pdf

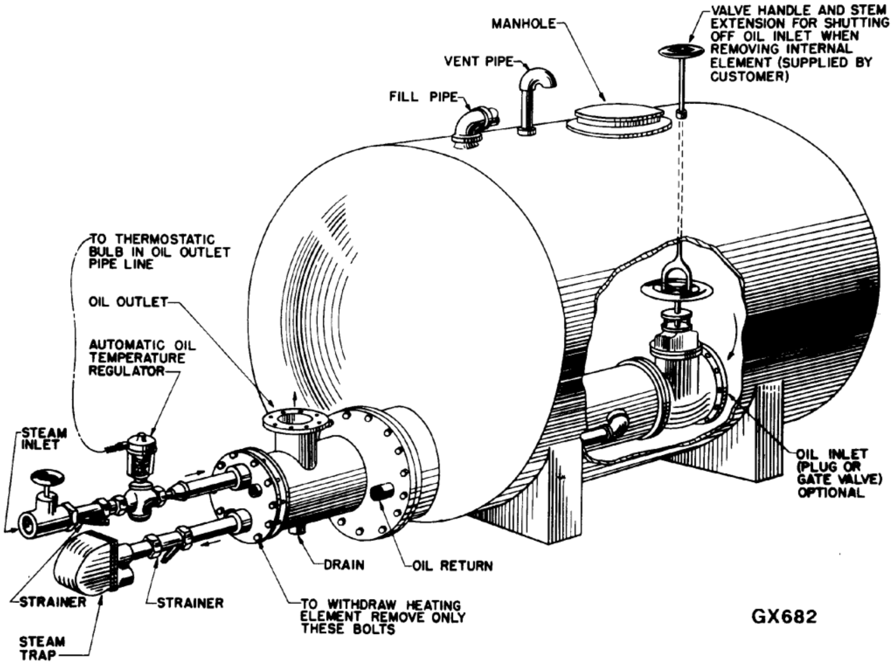
In an oil tank explain how to place the heaters into service.

On initial start-up, it is advisable to close the gate valve ahead of the fuel oil heater temperature control valve and to slowly introduce steam through the by-pass globe valve, to raise the oil temperature gradually. Avoid coking of the oil by initiating oil flow before admitting steam. When normal operating conditions are established, steam sent through the by-pass is closed. The oil temperature is adjusted to the desired temperature by changing the dial or spring tension. Heavy condensate load will be experienced during start-up if steam is used as a heating medium. Therefore, the condensate by-pass line should be open.

Power Plant Engineering pg. 3.71



GX683

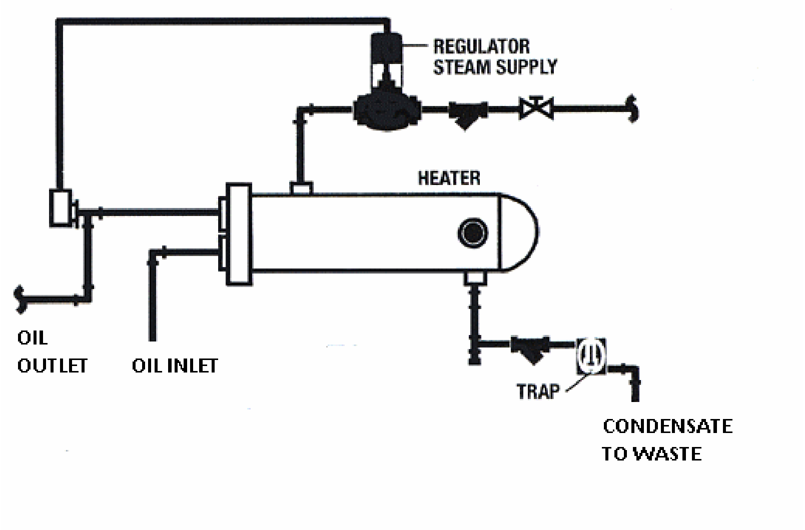

MANHOLE
VALVE HANDLE AND STEM EXTENSION FOR SHUTTING OFF OIL INLET WHEN REMOVING INTERNAL ELEMENT (SUPPLIED BY CUSTOMER)
VENT PIPE
FILL PIPE
TO THERMOSTATIC BULB IN OIL OUTLET PIPE LINE
OIL OUTLET
AUTOMATIC OIL TEMPERATURE REGULATOR
STEAM INLET
OIL INLET (PLUG OR GATE VALVE) OPTIONAL
DRAIN
OIL RETURN
STRAINER
STRAINER
TO WITHDRAW HEATING ELEMENT REMOVE ONLY THESE BOLTS
STEAM TRAP

GX682

From an oil tank heater, where does the condensate go?

The condensate should be piped to a separate tank where an oil contamination test is run on the condensate. If oil is found the oil/condensate mixture should be cleaned by a mechanical or chemical process before being discharged as waste. But regardless of oil contamination the condensate is always discharged to waste as a precaution against oil contamination.

Detroit Edison Steam Course - Boiler Operation



How is an oil tank heated that has no supply of steam or electric power?

Steam or hot water supplies the heat for tank heaters with electric auxiliary heaters. Steam generally is used, but some city ordinances require hot water heaters to insure control of maximum temperature. (They don't want tank temperature rising to the flash point.) A recirculating line off the discharge side of the suction heater can also send hot oil to the tank. Hot delivered oil pumped into the bottom of the tank can also heat the oil in the tank.

Kent’s 12th edition pg. 2-56

Another way of looking at this question is that the oil tank has no heat but the oil preheater before the pump does. In that case you would have to recirculate oil from the discharge of the pump back to the tank to heat the oil in the tank.

How would you detect water in an oil tank?

Use Gasoila water finding paste (reddish color) from tube.

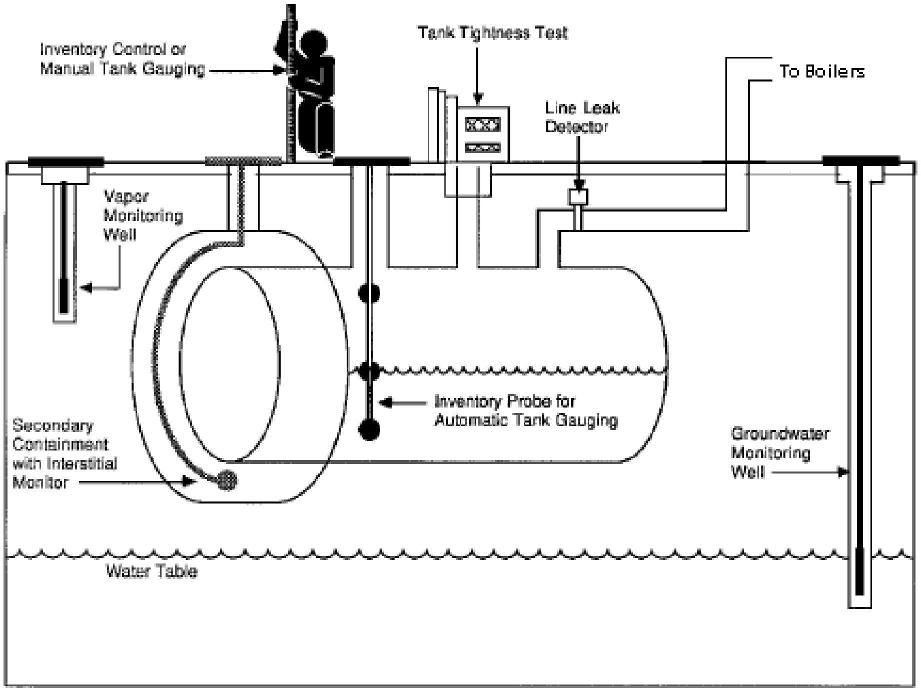
Smear a thin continuous film of Gasoila on a rod, install at expected water level, gauge the tank. Allow 10 seconds in gasoline and light distillates, 15 to 30 seconds in diesel and for heavy fuel oils.

The Gasoila is a mustard yellow in contact with hydrocarbons. It turns red in the presence of water. Read oil measuring stick at sharp line between red and yellow paste, this is the exact water level

Kolor Kut is another brand of water detecting paste. The paste remains a golden color from the tube and in the presence of oil but will turn a deep red immediately in the presence of water.

Chemist - Mistersky

How would you detect oil leaking from an underground storage tank?


Inventory Control or Manual Tank Gauging
Tank Tightness Test
To Boilers
Line Leak Detector
Vapor Monitoring Well
Inventory Probe for Automatic Tank Gauging
Secondary Containment with Interstitial Monitor
Groundwater Monitoring Well
Water Table

Michigan and the EPA now require all underground storage tanks to have monitoring of the area around the tank to determine any leakage.

Musts for USTs

Leaking Oil Tank showing rust holes after removal

What type of steam works best for atomizing fuel oil, wet, dry or superheated?

The steam admitted to the central passage of a steam atomizing oil burner should be as dry as possible for good atomization and for good heat transfer. Some preheating of the oil, together with a reduction in its viscosity is accomplished in this manner. Dry steam is good but superheated steam is better

Detroit Edison Steam Course Fuel Burning Equipment

Explain the procedure for start-up and shut-down of an oil train.

Using one pump and mechanical burner.

a. Walk down complete train noting valve positions, pressures, temperatures, any oil leaks, etc.

b. If oil heating in the tank is necessary then open by-pass around the tank heat temperature regulator valve slightly.

c. Open the by-pass around the condenser trap.

d. After oil is heated, close the two by-passes and place the auto temperature regulator in service.

e. Start the skid pump noting flows, temperatures,

f. Look in the furnace at the burner tip to insure rate valve is closed tight.

g. Open the by-pass around the skid heaters temperature regulator valve and condenser trap.

h. When the temperature of the oil is close to control set point temperature, close both bypasses and place auto temperature regulator into service.

i. Train is ready for light off.

Shut-down (After burners are off.)

a. Close heat supply to skid heaters.

b. Close heat supply to tank heaters.

c. Allow pump to run for about an hour to remove the residual heat from the heater then turn pump off.

d. Open by-passes around the heater condenser traps to drain heaters.

e. Close manual stop valve at the burners.

How do you start a steam atomizing burner?

A by-pass on the burner, when provided, should be opened to blowout the oil line, to clean it of any residual oil or refuse that may have collected. After this, the by-pass valve should be closed and the steam valve slowly opened. Any accumulation of water in the steam pipes is thus blown out. Next the oil valve is slowly opened and the oil spray ignited by a torch. After ignition has taken place and the furnace is heated, the steam should be adjusted to the minimum amount necessary for proper atomization. This amount will be evident from the appearance of the flame. Particles of burning oil will drop to the floor if there is not sufficient steam, whereas if there is too much steam the flame will be very white in color, short and in some cases have a tendency to go out. Next the air supply to the burner should be regulated to insure a proper amount of air for combustion.

Oil & Gas Burning Under Boilers International Text Book Company page 69

On a steam atomizing oil burner explain how to adjust the steam and oil proportions to the burner.

To respond to a load increase, first increase the draft by speeding up the I.D. fan followed by opening vanes to the inlet of the F.D. fan to increase air for combustion. Next, increase steam and then increase oil in increments until proper supply is obtained. Make the final adjustments to obtain a short, bushy, soft flame so that air has no difficulty penetrating it. Watch your O_2 meter for proper excess air requirements. Readjust the O_2 by proportioning the induced draft fan to the forced draft fan while maintaining a slightly negative pressure in the furnace.

To decrease load do the same procedure backward. Remember to lead with the reduction of oil first.

On an oil burner system, explain how to change from steam to air atomizing.

Assuming a one burner system:
1. Cut back the oil valve
2. Cut back on the steam valve until a low fire position is achieved.
3. Close the oil valve
4. Close the steam valve
5. Do a postpurge of the furnace
6. Increase furnace draft
7. Open the air valve to blow out the condensate
8. Place the igniter into operation
9. Slowly open the oil valve while watching for stable ignition.

What factors must be considered before deciding to run a boiler plant on #2 or #6 fuel oil?

When the heavier grades of oil (#6) are to be used, the tank must have steam coils for heating the oil and lowering its viscosity to facilitate pumping. It is well to have the tank heater, suction lines, return lines, in an enclosure within the tank to allow a small portion of oil to become heated to operating temperature while the remainder is at normal temperature. With this method the oil can be heated quickly, and the temperature is not materially changed when a supply of oil is added to the tank. Heaters near the pumps maintain a constant outlet oil temperature.

Steam Plant Operation by Woodruff and Lammers 4th edition page 196

These additional requirements are needed when burning #6 fuel oil, so one must consider the:

1. Cost of extra equipment
2. Extra fuel needed to keep #6 hot and circulating
3. Added maintenance and strainer cleaning
4. Problems with smoke
5. Clogged burner nozzles
6. Sulfur attack on boiler tubes and economizers
7. Soot and soot blowing expenses
8. Difficulty in startup from a completely cold system

The added costs of burning #6 must be added into the lower initial cost of #6 fuel oil.

What equipment is needed to successfully burn #6 fuel oil?

The fuel preparation system consists of the oil heater, oil temperature controls, strainers, and the associated valves and piping required to maintain the fuel oil temperature needed to control viscosity, to facilitate oil flow and burning, and to remove suspended matter. Grades #5 and #6 require heating to decrease viscosity to ensure proper flow through piping and so it can be atomized by the oil burner. Storage tank heaters usually are made of pipe coils or grids using steam or hot water at not over 15 psi pressure. To control viscosity for pumping, the heated oil surrounds the oil suction line inlet. For oils with high pour points, the heater should extend the entire length of the tank. Viscosity is regulated at the burners through temperature regulation, performed by heaters installed between the oil pumps and the burners. In large installations, the heater is mounted separately and is often arranged in combination with central oil pumps, all forming a central oil pumping and heating set. The oil heating capacity of any given installation should be 10% more than maximum oil flow (maximum oil burning rate plus rate of oil recirculation).

I.U.O.E. Fuels, Oils and Lubricants page 6-3-14

To get maximum heating of the fuel oil, should the oil heater be before or after the pump?

Tank heaters raise the oil temperature sufficiently to reduce the viscosity, thus facilitating straining and pumping. The heater located on **the high pressure side** of the pump lowers the viscosity so that it can be atomized effectively by the burners.

Steam Plant Operation 8th edition by Woodruff and Lammers page 308

Why should #6 fuel oil not be heated above 230 degrees F?

Heavy fuel oil, #6, for successful burning should be preheated to a temperature which results in the correct viscosity for atomization. Usually the viscosity requirements lay within the following: mechanical atomization 100 to 150 seconds Saybolt Universal, and for steam atomization, 150 to 300 SSU. An upper limit of 230º F has been established for preheating, as there is little change in the viscosity above this temperature, and may actually reduce burner capacity by increasing the specific volume of the oil. Overheating of the oil may cause fouling of the heaters and if intermittent vaporization occurs in the lines to the burner or in the burner, flame stability could be affected.

Detroit Edison Steam Course Fuel Burning Equipment page 18

What is the temperature of #6 fuel oil in the tank?

When pumping oil to storage tanks, or from them to oil heaters, a viscosity of 700 SSF is ordinarily used, and this requires heating to a temperature of approximately 100º F. The correct temperature viscosity relationship for each batch of oil should be determined, in order that overheating, with resultant precipitation of solids of suspension, may be avoided.

Blue Combustion Engineering page 10·14

Oil temperature at the pump inlet should not exceed 120º F.

I.U.O.E. Fuels, Oils and Lubricants page 6-3-13

What is the rate of oil consumption in gallons per hour on a mechanical atomizing, recirculating fuel oil burner?

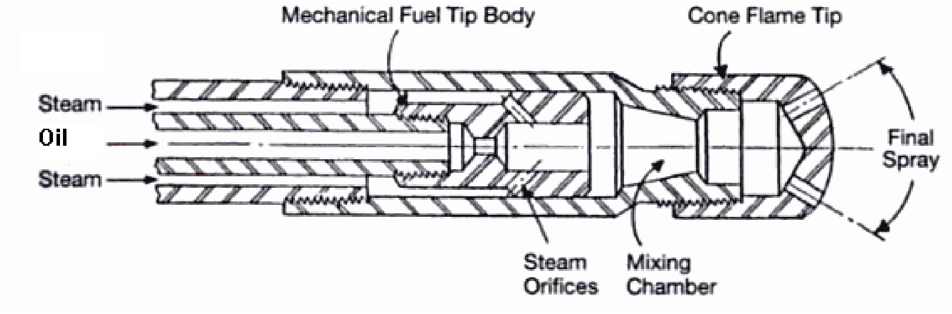
This burner has an oil consumption rate of between 25 and 1200 gallons per hour.

Honeywell Flame Safeguard Controls page 20

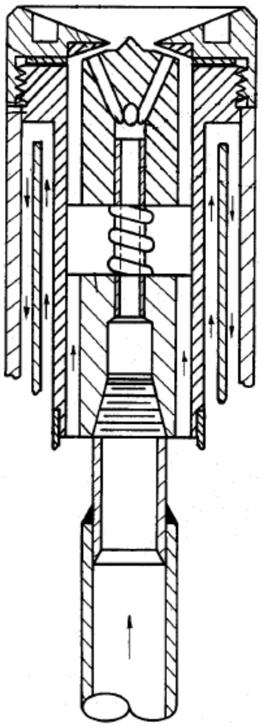
Describe an inside mix, an outside mix, and tip emulsion atomizing type of steam atomizing oil burner.

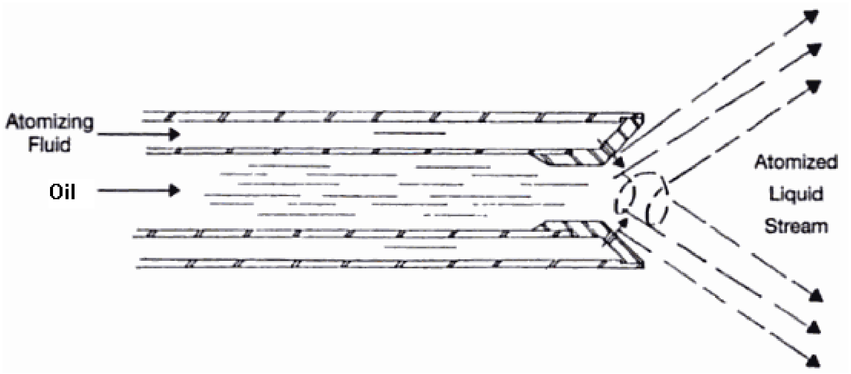
In the outside mixing burner, the steam and oil don't make contact until their release into the combustion chamber. The action of the atomizing steam shears the oil from the oil outlet orifice and delivers it in a spray. The nozzle causes both the steam and the oil to swirl before making contact, resulting in better mixing. This type generally requires more steam than the inside mixing burner, however, it is less susceptible to clogging and requires a lower oil pressure. In the inside mixing burner. the steam makes contact with the oil inside the burner, resulting in suspension of very finely divided oil in the steam. The mixture is called an emulsion, so the atomizer is sometimes called an emulsion atomizer. When the emulsion is discharged through the nozzle into the combustion chamber further atomization occurs. The steam nozzle or tip is interchangeable to permit a variety of flame shapes. This type is more commonly used than the outside mixing burner because it uses less steam and is therefore more economical. A variation of the inside mixing burner uses a tip emulsion, which has been found to be the most flexible for commercial and industrial boilers. In it, the steam and oil make contact just inside the tip of the atomizer. The resulting emulsion is forced through the nozzle orifice. The total pressure is almost completely converted to velocity pressure so the viscous friction separates the emulsified oil into minute droplets. The tip can be designed for a desired spray angle. This type does a better job of atomizing with lower steam pressure and less steam consumption, so it is most economical.

Honeywell Flame Safeguard Controls page 22



Internal Mix Steam Atomized Burner





Outside Mix Steam Atomized Burner

Tip Emulsion Burner

What percentage of boiler steam is required for steam atomized burners?

With careful operation, the steam required for atomization does not exceed 1% of the quantity generated by the boiler.

Steam Plant Operation by Woodruff and Lammers 5th Edition page 185

List the advantages and disadvantages of burning fuel oil over coal.

1. One of the main advantages of burning oil over coal is the fact that oil can be stored indefinitely with minimal chance of spontaneous combustion and no loss of heating value
2. Less equipment is required to burn oil. Oil contains less ash, so ash handling and labor costs are greatly reduced
3. Automatic combustion control is readily adapted to burning oil
4. The initial cost of oil is cheaper
5. The powerplant is cleaner compared to coal

Disadvantages

6. On the other hand, an advantage of burning coal is the fact that coal is readily available and in abundant supply at a relatively low cost which fluctuates less than oil.
7. Coal is not subject to OPEC
8. Cleaning of sludge from oil tanks is costly and troublesome
9. Plugged strainers and burners can lead to outages
10. Sulfur in oil is more detrimental to heating surfaces than sulfur in coal

Steam Plant Operation by Woodruff and Lammers 4th Edition pages 201 to 203

What do you do with newly installed oil piping to prevent plugging with dirt?

Blow out, with steam or compressed air, all newly installed piping serving the burners, to rid the system as much as possible of mill scale and other foreign material.

ASME Section VII Care of Power Boilers. Section C6.401(c)

Is the use of heavy oil mechanically atomized burners recommended for drying out, boiling out, lighting off, or raising pressure on steam generators equipped with air preheaters? Explain fully.

With low furnace temperatures, low firing rates, and high excess air, incomplete combustion of oil will result in an accumulation of unburned oil in the furnace and/or deposits of oily soot on the cool surfaces of the boiler unit. Under adverse operating conditions such as these, h is easier to obtain satisfactory combustion with mechanical atomizers that are designed for and used with light oil or with steam atomizers. However, poor atomization and careless operation may give trouble, regardless of the type of the atomizer and oil used. Therefore, as a precaution against the possibility of furnace explosions and fires in the air preheaters, economizers, and breaching, the use of mechanical atomizers with heavy fuel is not recommended for drying out, boiling out, lighting off, or raising pressure on boilers and steam generators equipped with flue gas air preheaters. If steam atomizing type burners or torches are used under these circumstances, steam rather than air should be used as the atomizing agent wherever possible.

ASME Section VII Care of Power Boilers Section C6.402(c)

Should you start a burner using an adjacent burner as an igniter? Explain.

Always light off the burner with setting at minimum rate, using a torch or other suitable ignition device. Do not attempt to light one burner from an adjacent operating burner or from hot furnace refractories. Maintain fuel-air ratio so as to always obtain complete combustion. Remember that with most gaseous fuels, CO_2 content of flue gases is not a measure of excess air; always be certain that burners are operated with sufficient air to insure complete combustion.

ASME Section VII Care of Power Boilers Section Cl. 112.

Describe different types of atomization, pressure, steam, air. Describe different flame shapes based upon different atomization principles.

PRESSURE TYPE BURNERS ARE also known as mechanical burners. Mechanical atomization is accomplished in several ways, depending upon the type and style of burner. In all types, however, the oil is set in a rotating motion and the centrifugal force of the rotating oil causes the oil to break up into a fine mist-like spray before the oil leaves the tip of the burner. An orifice in the tip is sized to meet the load requirement, and is changeable. As the oil leaves the orifice, the oil is a mist IN THE SHAPE OF A CONE.

The spray from the burner does not rotate although the flame from the burner does. The rotation of the flame is obtained by the manner in which the combustion air is admitted to the flame.

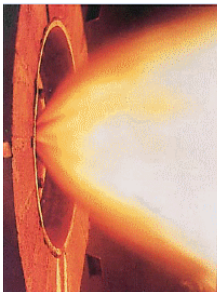
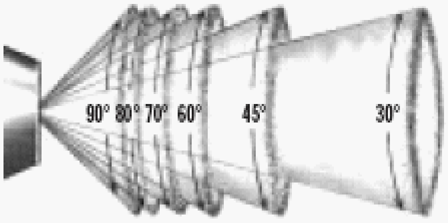
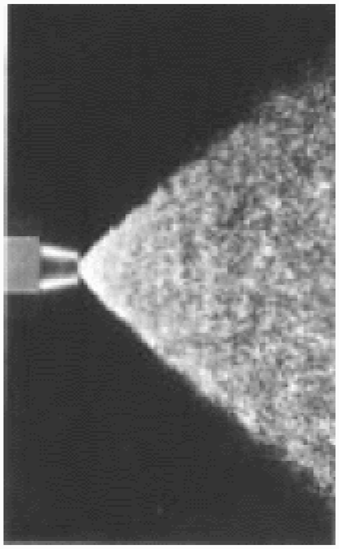
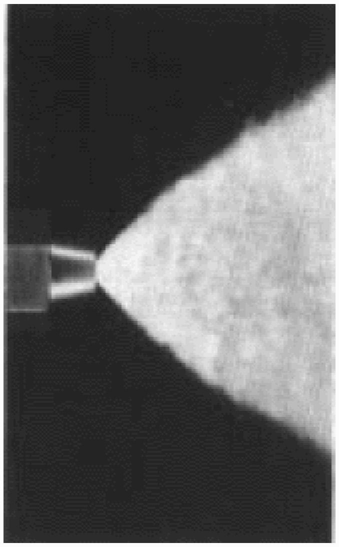


Figure 8
Spray angles available

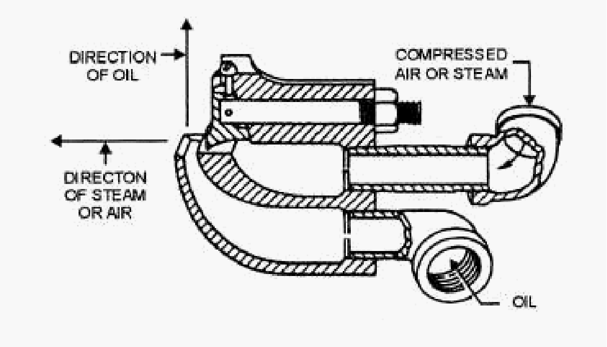



Spray at 100-psi pressure


Spray at 300-psi pressure

The OUTSIDE-MIX NOZZLES PRODUCE A FLAT FLAME, and the oil and steam do not mix until after passing through openings in the burner tip. Boilers equipped with this type burner can operate at comparatively high efficiency when limited to moderate capacities without wide fluctuation.

Outside mix flat oil flame



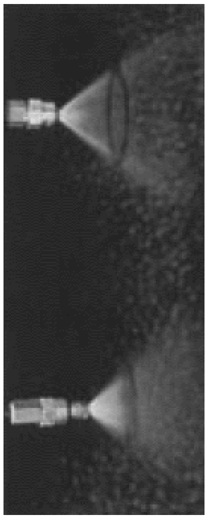
Outside Mix Burner

The INSIDE-MIX BURNER WILL GIVE A FLAT OR CONICAL SHAPE FLAME, depending on the design of tip used. The steam for atomization and the fuel oil are mixed inside the burner tip, after which they are projected into the furnace. The conical-flame steam atomizing burner is always of the inside mix type and is capable of high efficiency, with a wide range in capacity. The flame is short, bushy, and very soft so that the air has no difficulty in penetrating it rapidly to produce the thorough mixing which is so essential to high efficiency.

The use of burners in which air is used as the medium for effecting atomization has been limited to a very few industrial applications. The principal reason for this is the cost of supplying required compressed air, which is not offset by the lowered loss of sensible heat up the stack, as compared with that resulting from the use of steam for atomization, or as compared with the power charge for mechanical atomization.

When steam is used as an atomizing medium, the heat of the steam preheats the oil in the nozzle and reduces its viscosity, making it possible to burn a fairly wide range of fuels without changing the burner tip. The steam expands in flowing through the passages in the sprayer plate, picking up considerable velocity and reducing the oil to a fine mist-like spray for easy ignition and combustion. Steam atomizing burners are subdivided into two general groups, the outside mix and the inside mix depending on where the steam and oil mix, outside or inside the burner nozzle.

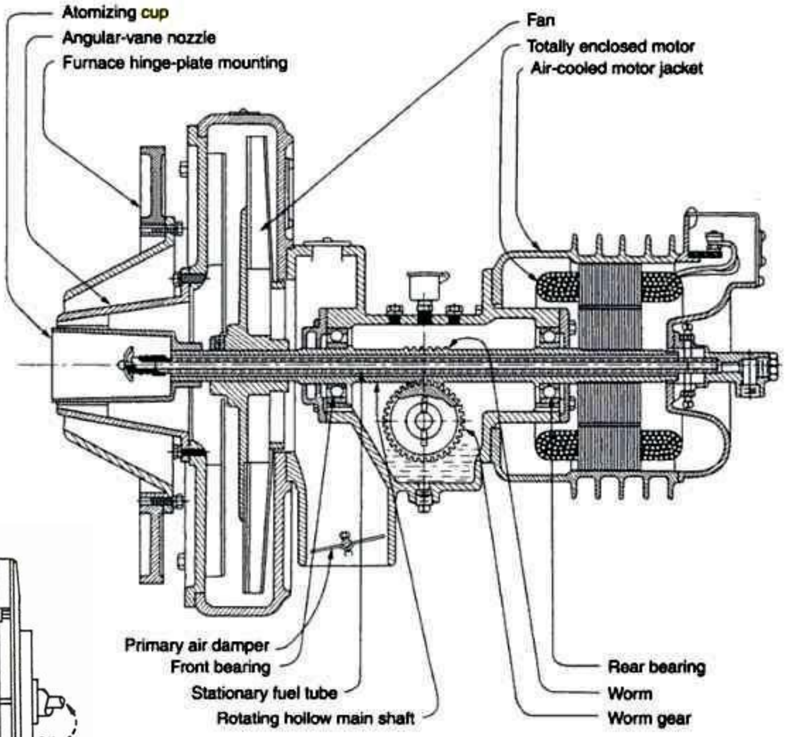
Blue Combustion Engineering page 10·6
Detroit Edison Steam Course Fuel Burning Equipment

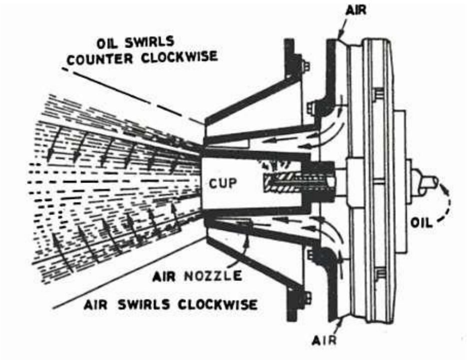


Inside Mix conical oil spray

Explain a Rotary Cup Burner

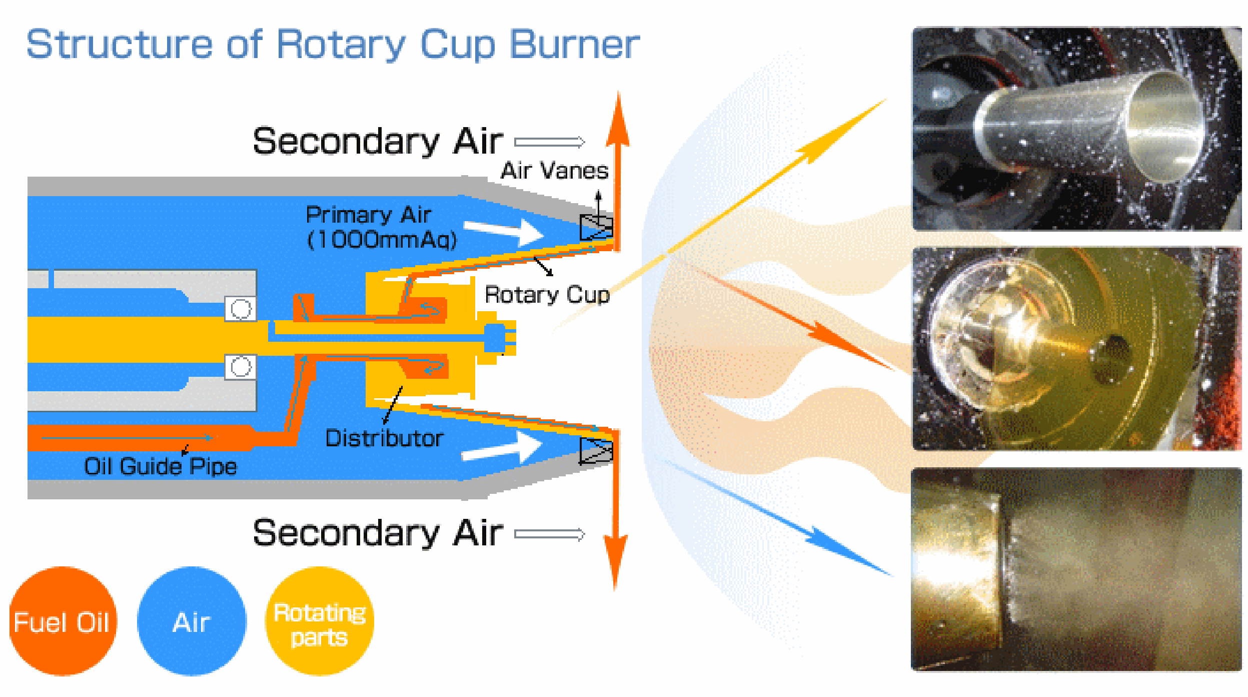
The rotary atomizer uses the energy from a spinning cup and primary air from a small fan. A thin cone of oil is spun off the end of the cup. Aided by the primary air fan, the oil thins out and breaks apart into fine droplets. Rotary Cup Burners can be fairly effective when combined forced draft fans. In general, rotary atomizers do not have any significant advantages over fluid and pressure types and are not used as often as the mechanically atomized or steam and air atomized types. They have the disadvantages of limited capacity and electric horsepower requirements for driving the rotary cup and the primary air fan.

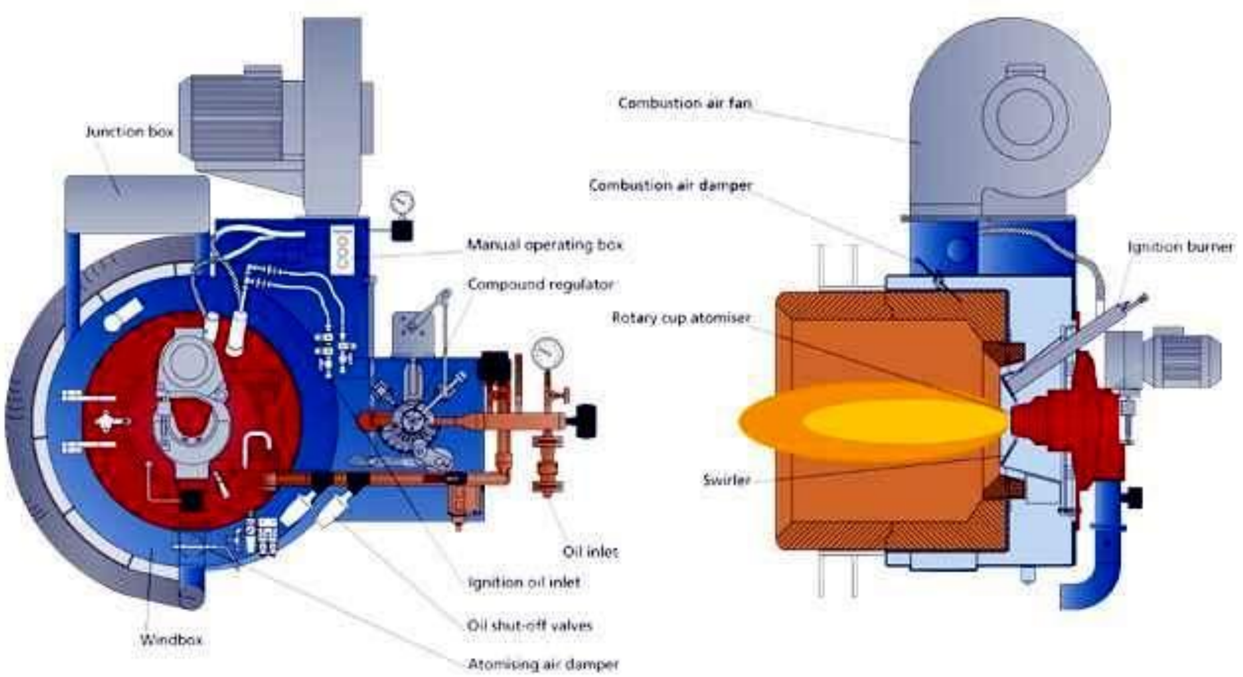




Looking at the rotary cup inside the burner.

Rotary cup burners burning #4 fuel oil at the old Stroh Brewery in Detroit. This is how they fire brewed the beer. The holes above the burners were where the lit kerosene soaked torches were inserted as the small quarter-turn valve on the oil line was opened. The flame used to shoot back six feet out the bottom air registers on start-up, which explains all the soot. The Brewer would insert the torch, turn the valve and run like Hell down the hallway. In order to extinguish the torch, which was a metal rod wrapped in asbestos rope, the Brewer would put it out by sticking it under the liquid level of the kerosene container. Very entertaining to watch.





The rotary cup must be taken out periodically and cleaned. It is first soaked in kerosene and then the deposits are cleaned with a piece of hardwood. The cone has a swirl pattern on it to help atomize the oil. Cleaning it with a wire brush will destroy the swirl pattern and the flame pattern will be ragged and smoky.

How much does one gallon of #6 fuel oil weigh?

Approximately 8 lbs. One cubic foot of fuel oil weighs 60 lbs. at 60 deg. F., and there are roughly 7.5 gallons per cubic foot.

Kent's 12th page 2-48

At what temperatures are the viscosity tests for fuel oil made?

100, 150, and 210 deg. F., plus or minus 0.25 deg. Viscosity is defined as the measure of the resistance to flow. Up to 250 deg. F., the viscosity of the oil decreases as the temperature increases, but above 250 deg., the viscosity is nearly constant. Because of this, some standard temperature must be used when testing for viscosity.

Blue Combustion Engineering page 2·42

All things being equal, you could check the viscosity of oil quicker by using the Saybolt Universal Viscosimeter or the Saybolt Furol Viscosimeter?

Saybolt Furol Viscosimeter.

Fuel oil is very viscous, and it takes a long time to make a determination with the Saybolt Universal viscosimeter. Saybolt Furol uses a larger orifice, otherwise the tests are the same. Viscosity of 62 seconds Saybolt Furol is equal to 600 seconds Saybolt Universal.

Blue Combustion Engineering page 2·42

Does oil that has been in storage lose its calorific value?

No.

One of the advantages of fuel oil is that it can be stored without danger of spontaneous combustion or deterioration. Fuel oil is often kept unhand as a secondary fuel, as opposed to coal, or natural gas.

Steam Plant Operation by Woodruff and Lammers Edition page 186

How much increase in stack temperature is allowed before blowing flues?

As a general rule, the flue gas temperature should not increase more than 35 deg F between soot blower operating periods.

When burning fuel oil, in addition to the regular periods, operate the soot blowers immediately after any abnormal burner operation that has resulted in heavy smoke. This is particularly important if an economizer or an air heater is installed. Also, operate the soot blowers as often as necessary to keep the boiler clean.

Blue Combustion Engineering page 30·26

As API specific gravity increases in fuel oil, the weight per gallon increases, what happens to the BTU/lb?

The BTU/lb decreases.

Heating value of fuel oil is expressed in BTU per gallon at 60 F., or per lb. The heating value per gallon increases with specific gravity, because there is more weight per gallon, and ranges from about 135,000 to 150,000 Btu. The heating value per lb of fuel oil varies inversely with the specific gravity, because lighter oil contains more hydrogen. It ranges from 18,300 to 19,500 Btu.

Blue Combustion Engineering page 2·42

As the specific gravity of fuel oil increases, what happens to the heating value per unit volume?

The heating value of fuel oils can be generally correlated with API gravity. The table below shows the relationship between heating value, API gravity, and density for various grades of fuel oil. When more specific data are lacking, the heating value of fuel oil may be calculated.

For uncracked distillate or residue:

higher heating value, btu/lb = 17,660 + (69 x API gravity for cracked distillate)

higher heating value, btu/lb = 17,780 + (54 x API gravity)

Typical gravity and heating value of standard grades

Grade No.	Gravity API	Weight lb per gallon	Heating Value btu per gallon
1	38-45	6.95-6.675	137,000-132,900
2	30-38	7.296-6.960	141,800-137,000
4	20-28	7.787-7.396	148,100-143,100
5L	17-22	7.94-7.686	150,000-146,800
5H	14-18	8.08-7.89	152,000-149,400
6	8-15	8.448-8.053	155,900-151,300

IUOE fuels furnaces burners page 6-1-10

If sulfur in #6 fuel increases, the BTU content would decrease or increase?

Decreases

Sulphur content will vary from 0.25% to 3% and 4%. When a pound of sulfur is burned, only 4000 Btu are liberated, as compared to 14,600 Btu for a pound of carbon, and 62,000 Btu per pound for hydrogen. Therefore, if there is a large amount of sulfur, there will be a decrease in percentage of carbon and hydrogen present, with a resultant lowering of the heat value.

Fuel Oil Manual by Paul F. Schmidt copyright 1986 page 51

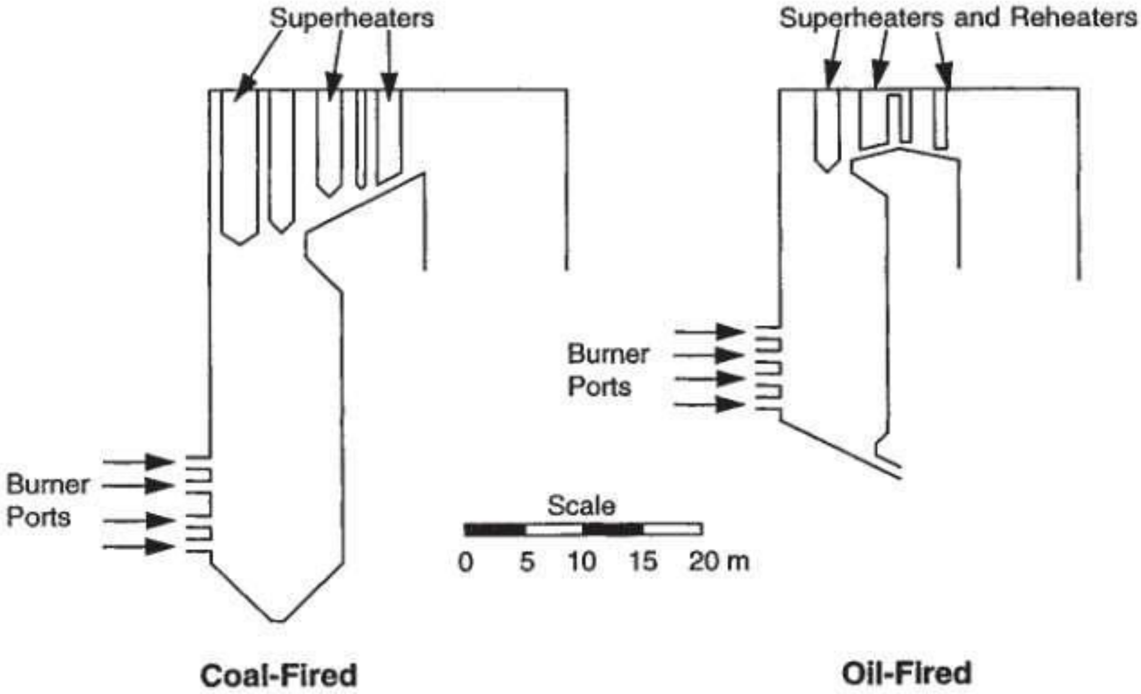
When burning fuel oil with pulverized fuel as an alternate, what does the design require of the furnace volume?

When the alternate fuel is pulverized coal, the furnace design factors are based on its use. As a result, the furnace volume is larger than would be required for operation with either oil or gas alone.

Blue Combustion Engineering page 10·20

The fuel which requires the largest furnace volume is used as the basis for selection and design. The furnace volume, as well as the governing dimensions of the unit, are determined from the requirements of satisfactory operation with pulverized coal. The furnace will be larger than would be required for either oil or natural gas, but nevertheless it is well suited for these alternate fuels.

Blue Combustion Engineering page 24·31



Comparison of the sizes and shapes of typical 500-MW, coal- and oil-fired boilers.

What is the best viscosity to keep at the burner tip of a mechanical atomized #6 fuel oil burner ?

For mechanical atomization, the oil requires greater fluidity and must therefore be heated to approximately 220 F to provide a viscosity of 180 to 200 SSU. The correct temperature/viscosity relationship for each batch of oil should be determined, in order that overheating, with resultant precipitation of solids out of suspension, may be avoided.

Blue Combustion Engineering page 10·14

After the maximum rate of combustion or any fuel has been established, what is the only method of increasing capacity?

After maximum rate of combustion for any fuel has been established, the only method of increasing capacity is to burn more fuel. The amount is limited by firing equipment and furnace volume.

Kent's 11th edition page 6-05

What amount of excess air is required to burn #6 fuel oil completely?

The amount of excess air, expressed in percent of the theoretical air, to burn #6 fuel oil completely is 8-15%.

Blue Combustion Engineering page 25·14

How much does one gallon of Bunker C weigh?

Bunker C weighs 8.63 to 8.10 lbs. per gallon. Bunker C oil has a density of 5 to 14 degrees A.P.I. according to Table XIV.

Croft Steam Boilers page 252 and 254

No. 6, known as Bunker C, according to Table 14-11 weighs 8.212 lbs. per U.S. gallon at 60 degrees F.

Combustion Engineering Revised Edition 2nd Impression pages 14·12 and 14·14

What is a good CO_2 reading for #6 fuel oil?

12.6% CO_2 is a good reading for #6 fuel oil.

Detroit Edison Steam Course Fuels & Combustion page 32

When air leaks through a furnace setting, what is the most important result; the lowering of furnace temperature, the need of more air for combustion, or a lower CO_2 reading?

A lower CO_2 reading

Air leaks into the furnace gas if the furnace setting or air casing is not tight. The reading then shows high excess air (low CO_2) at the boiler exit as there is a deficiency of air through the burners and in the furnace. When the boiler uptake shows a high excess of air, yet furnace conditions show a deficiency, take readings at the top of the first pass. A drop in CO_2 of over 0.5% from the first pass to the boiler exit shows a need to seal against leaks. Air entering through the walls or floor, especially at reduced capacity, cools the flame and may cause smoke or carbon.

Standard Plant Operator's Questions and Answers page 343

When you have a long term loss of load on a mechanically atomized fuel oil burner, what would you do?

Change the burner tip.

The operating range of a given atomizer-tip orifice is limited to approximately 1 ½ to 1, with an oil pressure change of as much as 200 psi. Any reduction in pressure below a minimum of 50 psi will result only in a coarser spray, drooling, unstable ignition, and other similar and generally unsatisfactory operating conditions. These designs are therefore best suited for relatively constant loads and high capacity. For satisfactory operation over reasonably wide load ranges, it is necessary to have a multiplicity of burners, as well as several sizes of atomizer assemblies for each burner. Then, by cutting in and out, and also quickly changing size of atomizers, it is possible reasonably to follow load swings, provided they come at infrequently occurring intervals and are not of the widely fluctuating type. Even under these conditions, it is quite possible to be caught with small atomizers in the burner at the time of rapidly increasing load.

Blue Combustion Engineering page 10·12 and 10·13

When you have a temporary loss of load on a mechanically atomized fuel oil burner, what would you do?

The pressure on the oil has no effect on the fineness of the oil spray, but it does affect the oil quantity. For this reason, the pressure of the oil must be reduced in order to reduce the burning rate, but the velocity of the oil leaving the nozzle should be maintained in order to maintain proper atomization.

Detroit Edison Steam Course Fuel Burning Equipment page 17

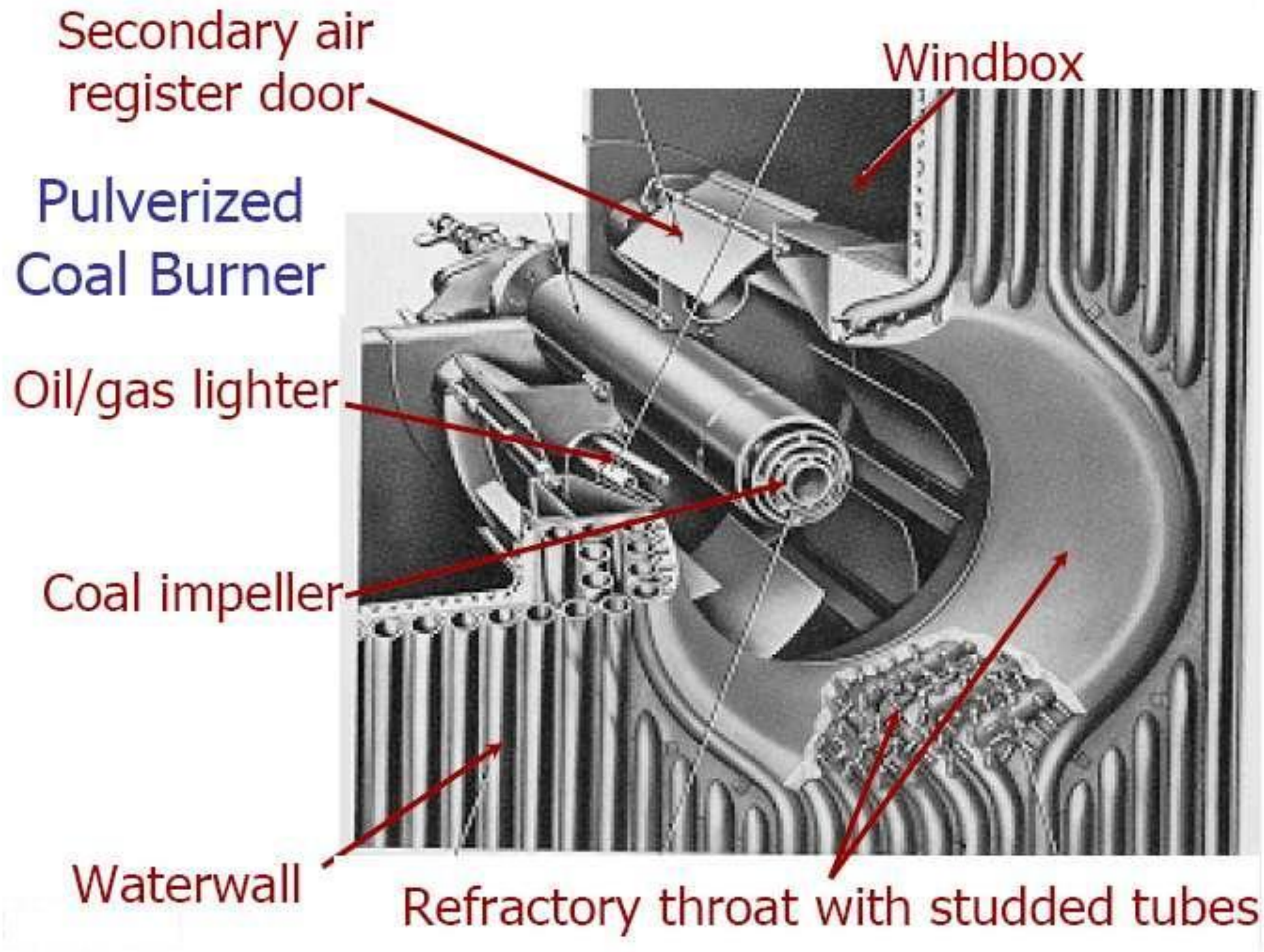
When you change a boiler firing pulverized fuel over to fuel oil, does the boiler capacity increase or decrease?

Boiler capacity is increased.

Pulverized coal furnace volume usually is larger or the heat release rates lower than in furnaces of equal capacity burning any other fuel.

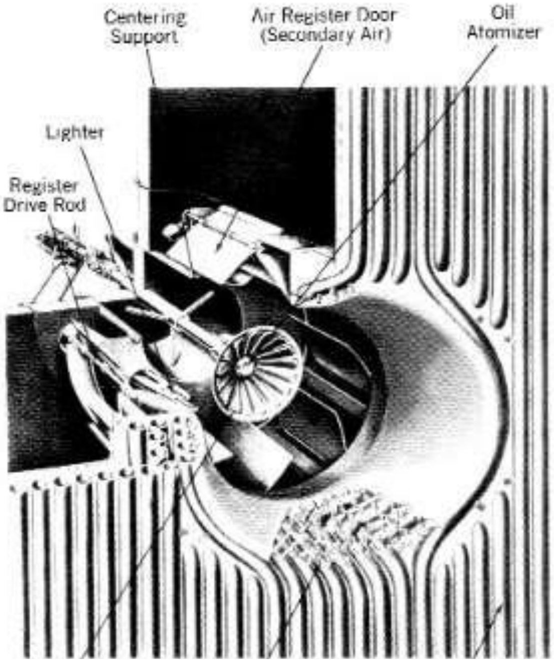
Blue Combustion Engineering, page 7·75
Kent's 12th Edition, page 2-13 Table 1

Describe a combination Fuel oil/ gas/ Pulverized Coal Burner

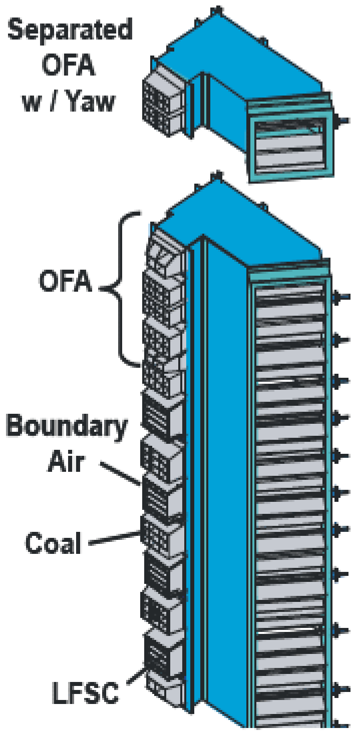


In the direct fired system, the coal is dried and delivered to the furnace in suspension in the primary air. Secondary air is mixed with the primary air/coal mixture at the burner. Tertiary or third source air is added around the burner to ensure complete combustion of the pulverized coal. The windbox surrounds the coal nozzle and air is admitted through air register doors or vanes that encircle and surround the periphery of the coal nozzle. Oil and gas guns are used to ignite the pulverized coal. Sometimes these guns are large enough to warm up the turbine and put the turbine on the line before starting the pulverized coal burners. The gas guns can be used at the same time as the pulverized coal to ensure stable ignition, but the oil guns can cause problems with coking of the coal nozzle if run together for long periods. Large boilers with air preheaters require 6 hours at full load for temperatures throughout the unit to stabilize. Pulverized coal requires more excess air for satisfactory combustion than either oil or natural gas.

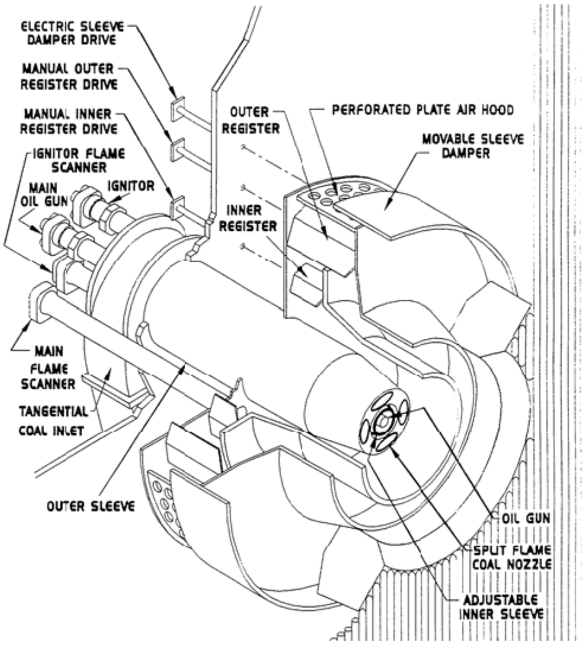
Steam, Its Generation and use 39th edition pages 9-11 to 9-13



The burners on the left have an oil gun in the center and will be surrounded by pulverized coal when in operation.



Foster Wheeler Corner fired burner. OFA stands for overfire air. Yaw is the movement of the air nozzle. LFSC is Lower Furnace Stoichiometry Control. It was developed to control the fuel-rich, lower furnace conditions created during deep-staged low NOx combustion. These lower furnace conditions are a common source of CO formation. The LFSC allows independent flow and direction control of lower windbox secondary air under the main fireball. LFSC experience has also shown NOx benefits as well especially when firing some types of coals.



The expansion of fuel oil is .0004 by volume per degree degrees Fahrenheit. If 15,500 gallons were delivered at 148F, how many gallons would you have paid for if the oil was at 60 degrees Fahrenheit?

The fuel oil at 148 degrees Fahrenheit will have a greater volume than at 60 degrees Fahrenheit

The volume will be decreased by a factor ev x (T1-T2).

Therefore, V = V x (1-ev x (T1-T2)
V = V x 1 - V x e (T1-T2)
V = 15,500 - 15,500 x .0004 x (148-60)
V = 15,500 - 15,500 x .0352
V = 15,500 - 545.6 = 14,954.4 gallons at 60 degrees Fahrenheit

So you would have paid for 14,954.4 gallons if the oil were delivered at 60 degrees Fahrenheit

Chapter 11 Natural Gas and Other Gases

Which is heavier natural gas or air?

Specific Gravity:

Air = 1.000

Natural Gas = .6655

Weight in lb/ft.3:

Air = .07658

Natural Gas = .05140

Therefore air is heavier than natural gas.

NOTE: To obtain exact characteristics of natural gas, the exact constituents must be known.

Kent's 12th edition page 1-40

Is natural gas odorless and colorless?

Natural gas is an almost odorless and colorless gas that accumulates in gas wells and in the upper parts of oil well. Raw natural gas is a mixture of methane (55 to 98%) higher hydrocarbons (mostly ethane), and noncombustible gases. Constituents such as water vapor, hydrogen sulfide, helium, liquefied petroleum gases and gasoline are removed before the natural gas is distributed to the user.

IUOE Fuels Furnaces & Burners page 6-1-14

What is the odorant added to natural gas?

Mercaptans (odorants) are added to natural gas to give it a characteristic odor for safety purposes.

I.U.O.E. Fuels Oils & Lubricants, page 6-1-4

A mercaptan is a liquid of a strong garlic odor consisting of an alcohol radical in combination SH; so named for its energetic action on mercury.

Dictionary definition

It eez like perfume, oui?

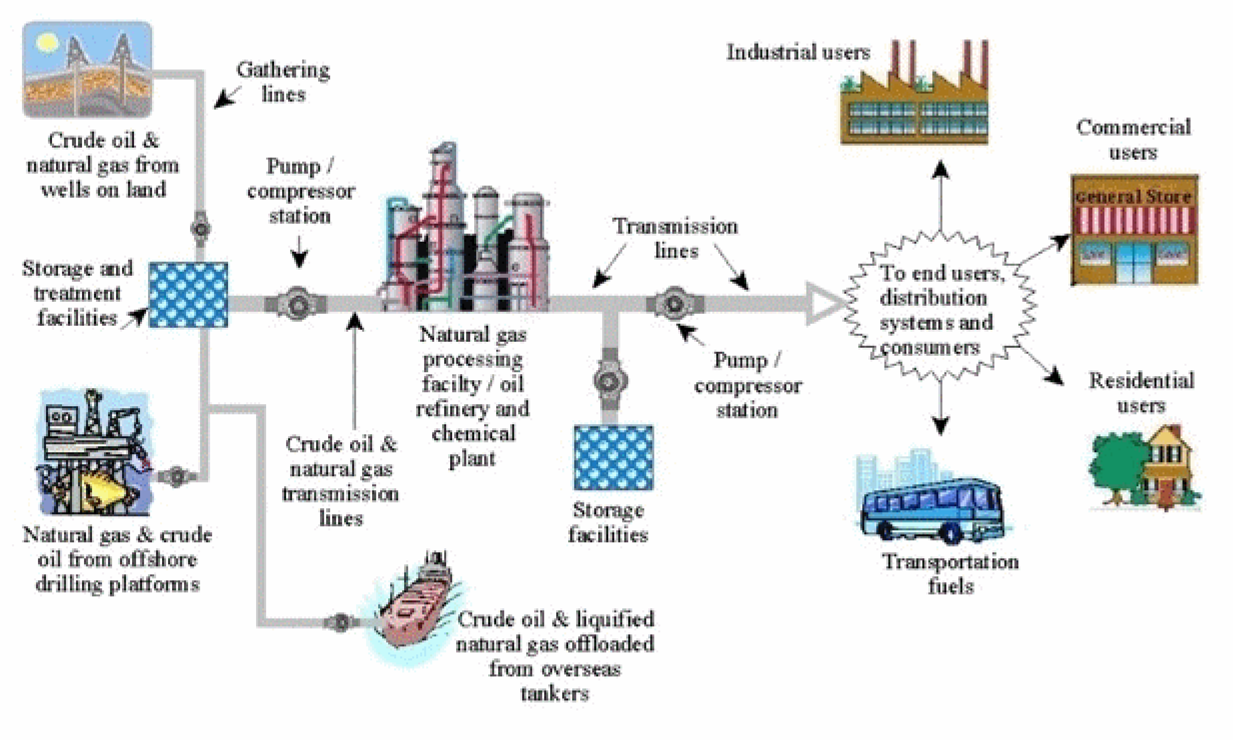
Explain the pressures of natural gas from the wellhead until it reaches the burner.

When so called gas bearing sands of a pool are tapped by drilling wells, the gas is found to be under rock pressure, which may be as high as 2000 psi. As gas is withdrawn, this pressure gradually decreases until it eventually becomes so low that the field must be abandoned. The use of high pressures for pipeline transportation of gas over long distances is necessary to maintain low production costs.

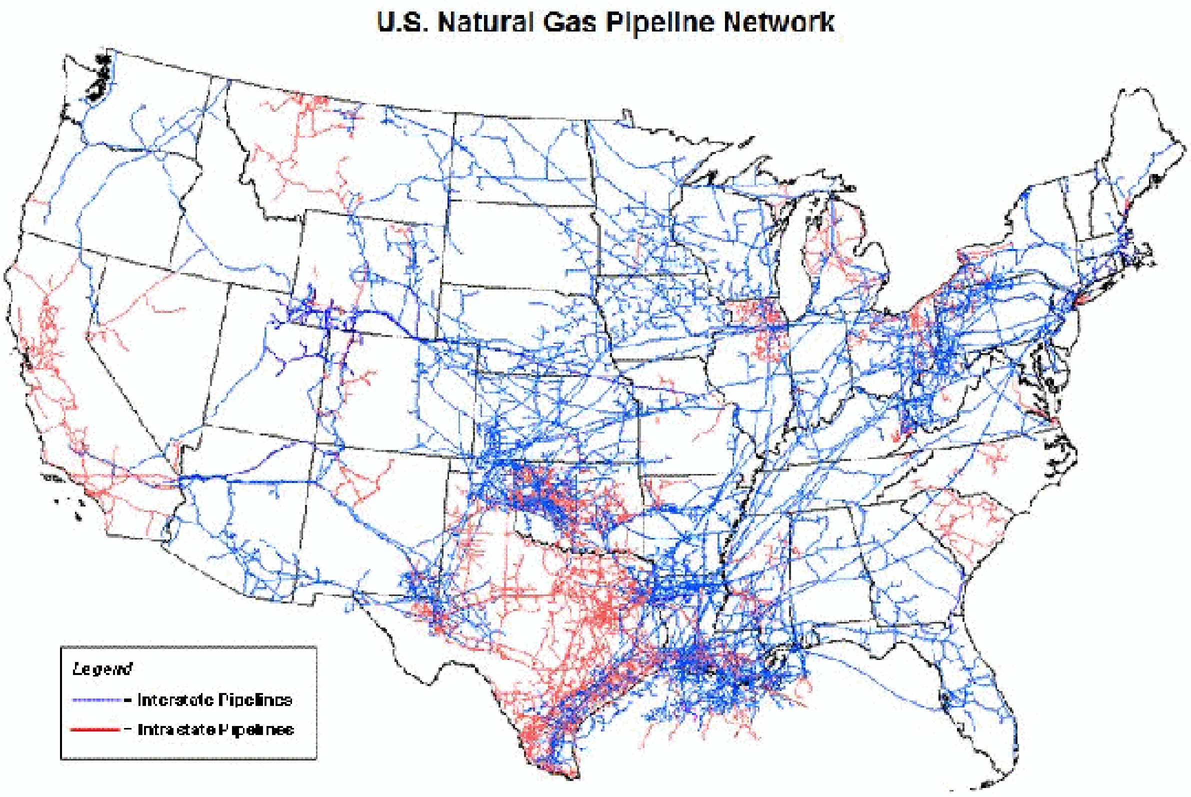
Combustion Engineering, page 11·6

Because of this, practically all the large gas fired installations are equipped with burners which operate on pressures from 2 to 25 psi. The pressure in the gas main serving a plant may vary as much as from 30 to 50 psi. Regulators are used to provide the required pressure step down to the burner mains, and to maintain a constant pressure in them so that automatic controls are effective in varying the gas flow to meet fluctuations in steam demand. Low pressure burners are usually designed for relatively small capacities, and operate with natural gas at a pressure of from 1/8 to 4 psi.

Combustion Engineering, page 11·6, 11·8


Gathering lines
Crude oil & natural gas from wells on land
Pump / compressor station
Storage and treatment facilities
Natural gas & crude oil from offshore drilling platforms
Crude oil & natural gas transmission lines
Natural gas processing facilty / oil refinery and chemical plant
Transmission lines
Pump / compressor station
Storage facilities
Crude oil & liquified natural gas offloaded from overseas tankers
Industrial users
Commercial users
General Store
To end users, distribution systems and consumers
Residential users
Transportation fuels

Interstate pipelines are the 'highways' of natural gas transmission. Natural gas that is transported through interstate pipelines travels at high pressure in the pipeline, at pressures anywhere from 200 to 1500 pounds per square inch (psi). This reduces the volume of the natural gas being transported (by up to 600 times), as well as providing propellant force to move the natural gas through the pipeline. Mainline pipes, the principle pipeline in a given system, are usually between 16 and 48 inches in diameter. Lateral pipelines, which deliver natural gas to or from the mainline, are typically between 6 and 16 inches in diameter. Most major interstate pipelines are between 24 and 36 inches in diameter. Natural gas is highly pressurized as it travels through an interstate pipeline. To ensure that the natural gas flowing through any one pipeline remains pressurized, compression of this natural gas is required periodically along the pipe. This is accomplished by compressor stations, usually placed at 40 to 100 mile intervals along the pipeline. The natural gas enters the compressor station, where it is compressed by either a turbine, motor, or engine.

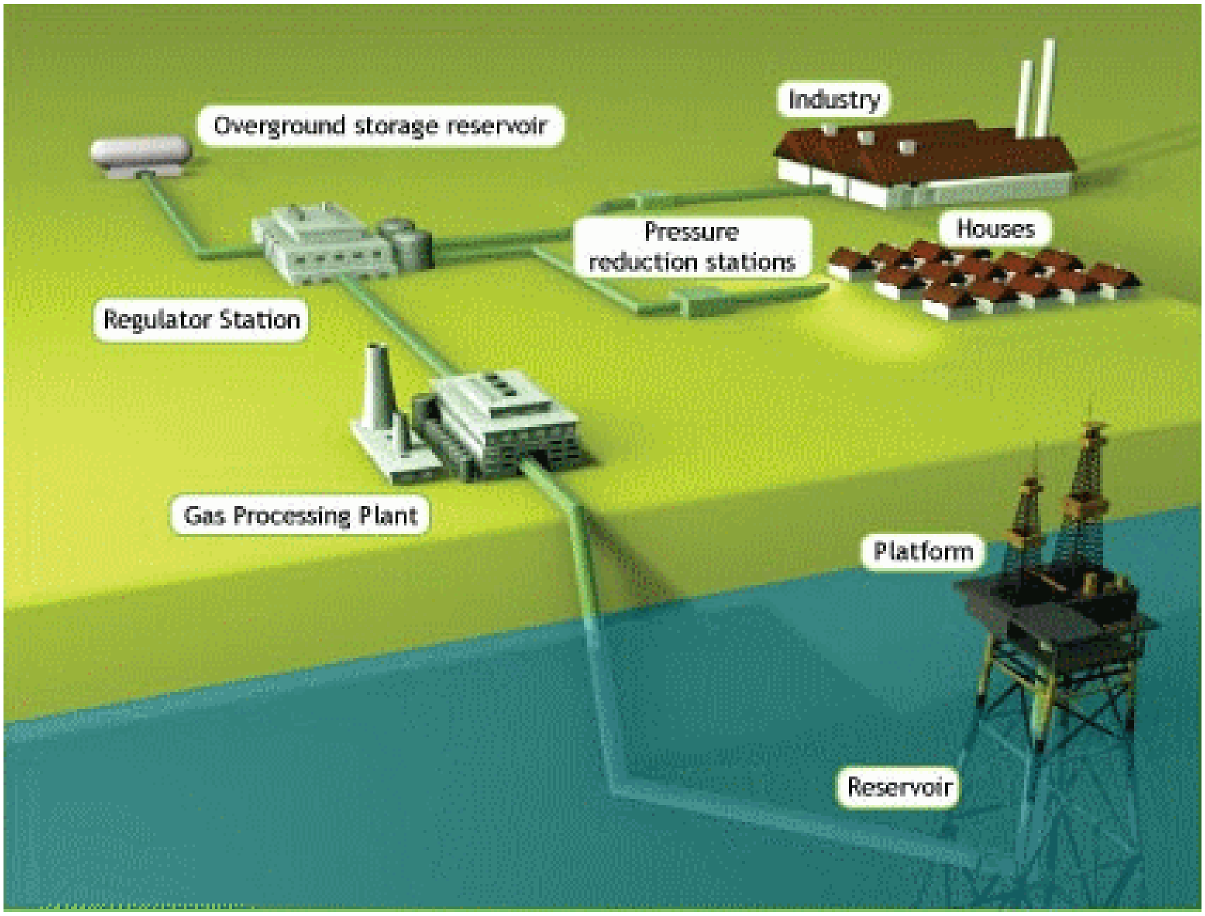

U.S. Natural Gas Pipeline Network

Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System

Turbine compressors gain their energy by using up a small proportion of the natural gas that they compress. The turbine itself serves to operate a centrifugal compressor, which contains a type of fan that compresses and pumps the natural gas through the pipeline. Some compressor stations are operated by using an electric motor to turn the same type of centrifugal compressor. This type of compression does not require the use of any of the natural gas from the pipe, however it does require a reliable source of electricity nearby. Reciprocating natural gas engines are also used to power some compressor stations. These engines resemble a very large automobile engine, and are powered by natural gas from the pipeline. The combustion of the gas powers pistons on the outside of the engine, which serves to compress the natural gas.

In addition to compressing natural gas, compressor stations also usually contain some type of liquid separator, much like the ones used to dehydrate natural gas during its processing. Usually, these separators consist of scrubbers and filters that capture any liquids or other undesirable particles from the natural gas in the pipeline. Although natural gas in pipelines is considered 'dry' gas, it is not uncommon for a certain amount of water and hydrocarbons to condense out of the gas stream while in transit. The liquid separators at compressor stations ensure that the natural gas in the pipeline is as pure as possible, and usually filters the gas prior to compression. http://www.naturalgas.org/naturalgas/transport.asp

GE *PGT25+* turbine for pressurizing a natural gas pipeline



List the pressures of natural gas from the wellhead in Oklahoma through the ANR pipeline, through Michigan Consolidated Gas Lines, to the powerhouse, to the burner in a boiler?

1,200 psi from the wellhead to Michcon; 500 psi from Michcon to the intrastate distribution network; 30-50 psi in the pipe running down the street; 1-2 psi in your house; 7-9 oz at the burner.

The pressures from the wellhead to the holding fields or the pipeline vary too much to give a specific pressure. Although the pressures listed above could very well be in the system at any time.

Gary Dylan, EMC Gas Transmission Company
Tim Miller, Distribution Engineer, ANR Pipeline Company

Once the gas is in the state, provided it is gas from out of the state, the pressures given above are accurate. If the gas is from within the state the pressures are dependent on the condition of the well.

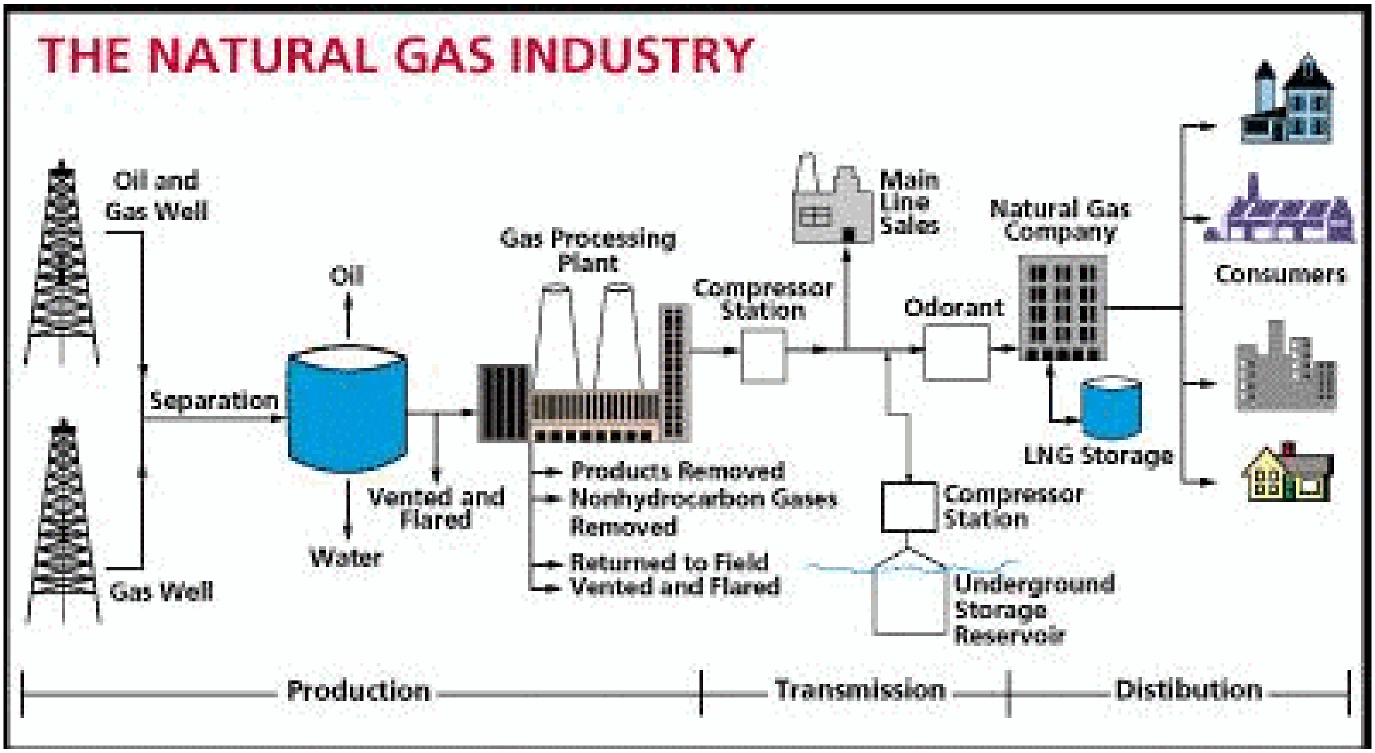
This information was provided by Bob Minot, a Gas Purchaser, with Michigan Consolidated Gas Co.

The use of high pressures for pipeline transportation of gas over long distances is necessary to maintain low production costs. Because of this, practically all the larger present day gas fired installations are equipped with burners which operate on pressures of from 2 to 25 psi. The pressure in the gas main serving a plant may vary as much as from 30 to 50 psi. Regulators are used to provide the required pressure step-down to the burner mains, and to maintain a constant pressure in them so that automatic controls are effective in varying the gas flow to meet fluctuations in steam demand.

Blue Combustion Engineering page 11·8

How is natural gas pressure kept up in traveling from Oklahoma to Michigan?

The gas is compressed by booster stations with centrifugal and/or turbine compressors.



What is "wheeling" of natural gas?

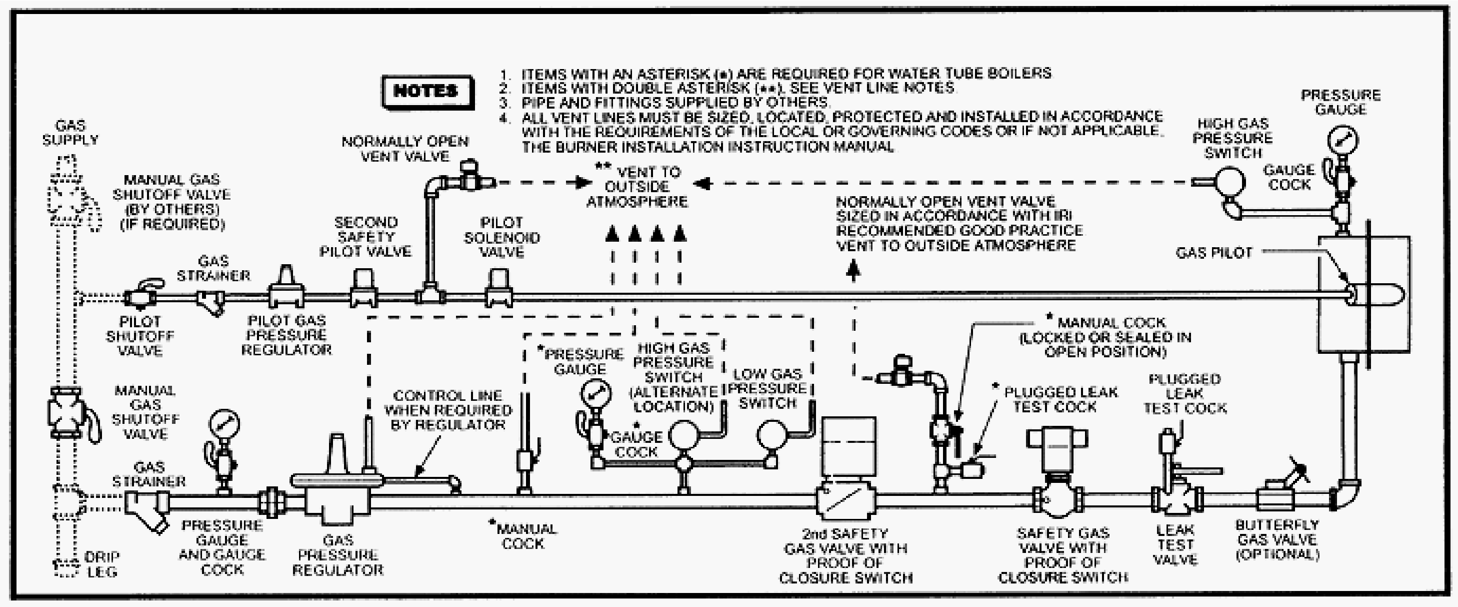
Wheeling is the transfer of one's utility's energy over another utility lines to deliver to a third party

Encyclopedia of Technical Terms

What are the constituents of natural gas?

Gas fuels are those in a gaseous or vapor state, most of them invisible. The most abundant gas fuel is natural gas, the origin of which is uncertain. Natural gas is mostly hydrocarbons; methane, ethane and propane. Natural gas is often found associated with crude oil, but there are some gas fields where little or no crude oil is encountered.

Draw and explain a gas train

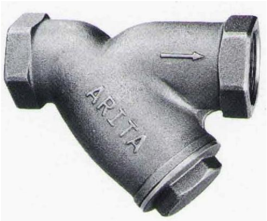


NOTES

1. ITEMS WITH AN ASTERISK (*) ARE REQUIRED FOR WATER TUBE BOILERS
2. ITEMS WITH DOUBLE ASTERISK (**). SEE VENT LINE NOTES
3. PIPE AND FITTINGS SUPPLIED BY OTHERS.
4. ALL VENT LINES MUST BE SIZED, LOCATED, PROTECTED AND INSTALLED IN ACCORDANCE WITH THE REQUIREMENTS OF THE LOCAL OR GOVERNING CODES OR IF NOT APPLICABLE, THE BURNER INSTALLATION INSTRUCTION MANUAL

GAS SUPPLY
MANUAL GAS SHUTOFF VALVE (BY OTHERS) (IF REQUIRED)
NORMALLY OPEN VENT VALVE
** VENT TO OUTSIDE ATMOSPHERE
SECOND SAFETY PILOT VALVE
PILOT SOLENOID VALVE
GAS STRAINER
PILOT SHUTOFF VALVE
PILOT GAS PRESSURE REGULATOR
NORMALLY OPEN VENT VALVE SIZED IN ACCORDANCE WITH IRI RECOMMENDED GOOD PRACTICE VENT TO OUTSIDE ATMOSPHERE
HIGH GAS PRESSURE SWITCH
PRESSURE GAUGE
GAUGE COCK
GAS PILOT
MANUAL GAS SHUTOFF VALVE
GAS STRAINER
CONTROL LINE WHEN REQUIRED BY REGULATOR
*PRESSURE GAUGE
HIGH GAS PRESSURE SWITCH (ALTERNATE LOCATION)
LOW GAS PRESSURE SWITCH
*GAUGE COCK
* MANUAL COCK (LOCKED OR SEALED IN OPEN POSITION)
* PLUGGED LEAK TEST COCK
PLUGGED LEAK TEST COCK
DRIP LEG
PRESSURE GAUGE AND GAUGE COCK
GAS PRESSURE REGULATOR
*MANUAL COCK
2nd SAFETY GAS VALVE WITH PROOF OF CLOSURE SWITCH
SAFETY GAS VALVE WITH PROOF OF CLOSURE SWITCH
LEAK TEST VALVE
BUTTERFLY GAS VALVE (OPTIONAL)

This is a good drawing of a gas train for a large boiler. We will go down each line starting with the pilot line on the top. First we have the pilot shutoff valve, the gas strainer, and the pilot gas pressure regulator.

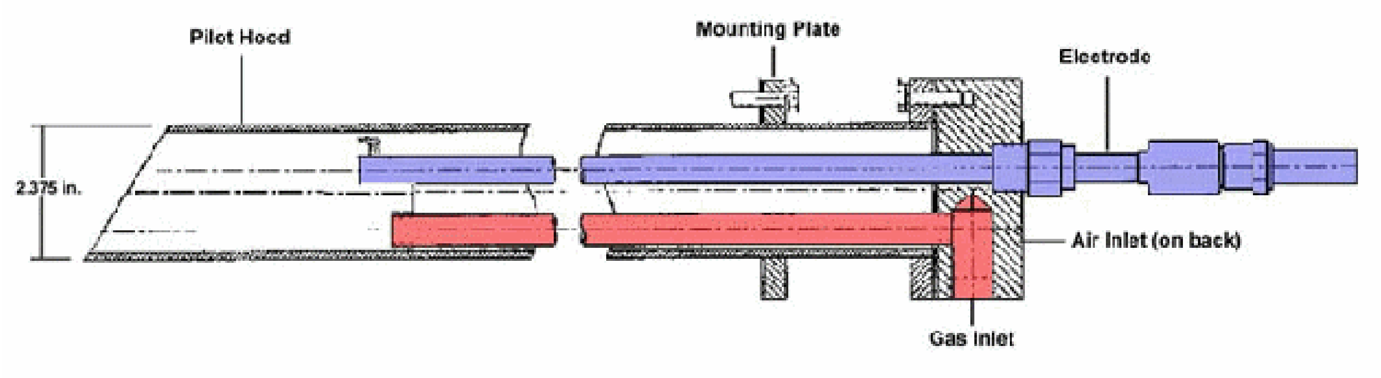


Then we have the normally closed solenoid in the gas line, the normally open solenoid in the vent line, followed by another normally closed solenoid in the gas line to the pilot ignitor.

Normally open solenoid

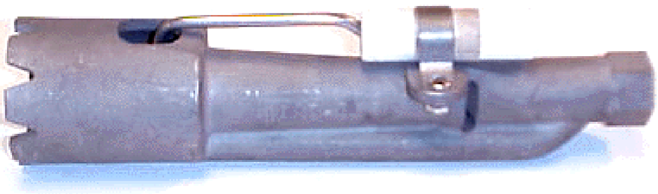
Normally closed solenoid

Normally closed solenoid



The pilot assembly consists of an electrode that will spark when the high voltage is applied as the solenoids open to ignite the pilot flame

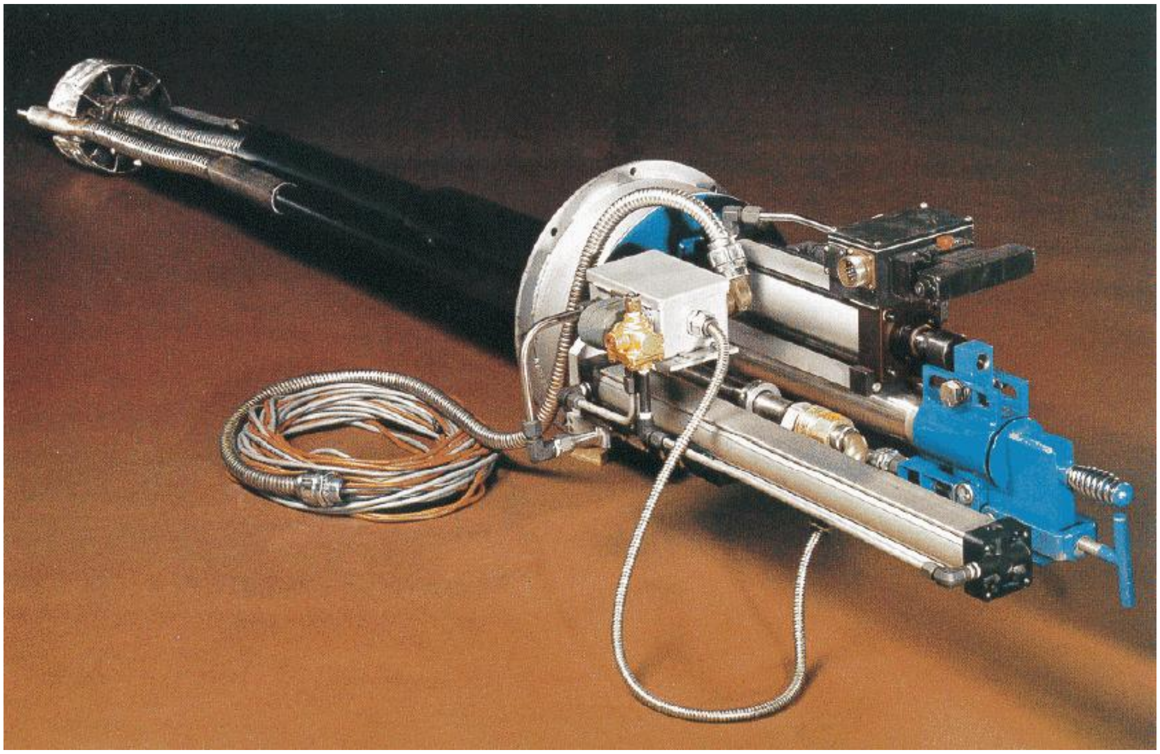
The ignitor consists of a "spark plug" type device at the end of the main burner so that the pilot will ignite the main burner after the pilot flame has been proven by the flame scanner like the Fireye.



Another style of pilot ignitor

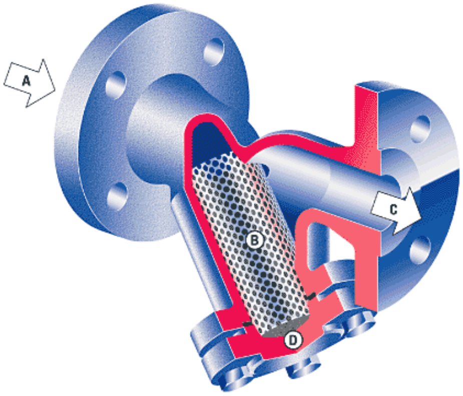
Fireye flame scanner

The fire end of the pilot ignitor



Gas Ignitor and gas gun

In the main vertical gas line there is manual shut off valve



Followed by a large gas strainer and a large gas pressure regulator.

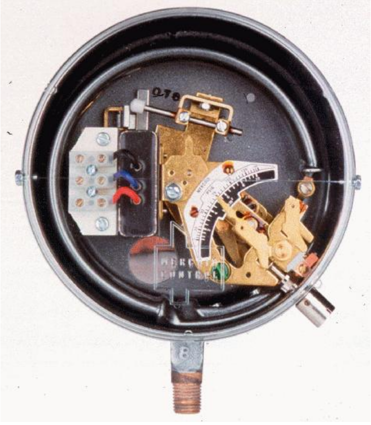
The gas pressure regulator type serves to ensure a constant outlet pressure when the inlet pressure or flow capacity varies. It is found in industrial gas burners for boilers where a short response time is required. Because of spring loading, the installation is possible in any position.

The gas flows through the regulator housing in arrow direction. The main diaphragm is actuated via an impulse line from the outlet side by pressure. The required outlet pressure is adjusted at the spring. The valve remains open as long as the outlet pressure is below the set value. When reaching the set point the regulator valve closes.

The regulator is followed by a test gage, a low gas pressure switch, a Maxon safety shut-off, a normally open vent solenoid to prevent gas accumulation in a shut down boiler, another Maxon safety shut off valve followed by a modulating butterfly valve to control firing rate, followed by another large manual shutoff valve.

Low gas pressure safety switch

Normally Open Vent Solenoid



High Gas Pressure safety switch with cover removed to show the Bourdon tube actuating mechanism

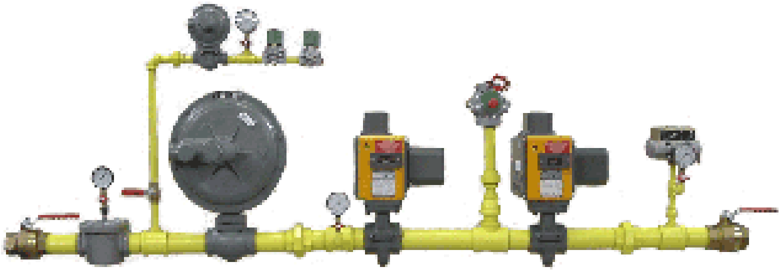
First Maxon Valve with manual reset handle

Second Maxon safety shutoff valve

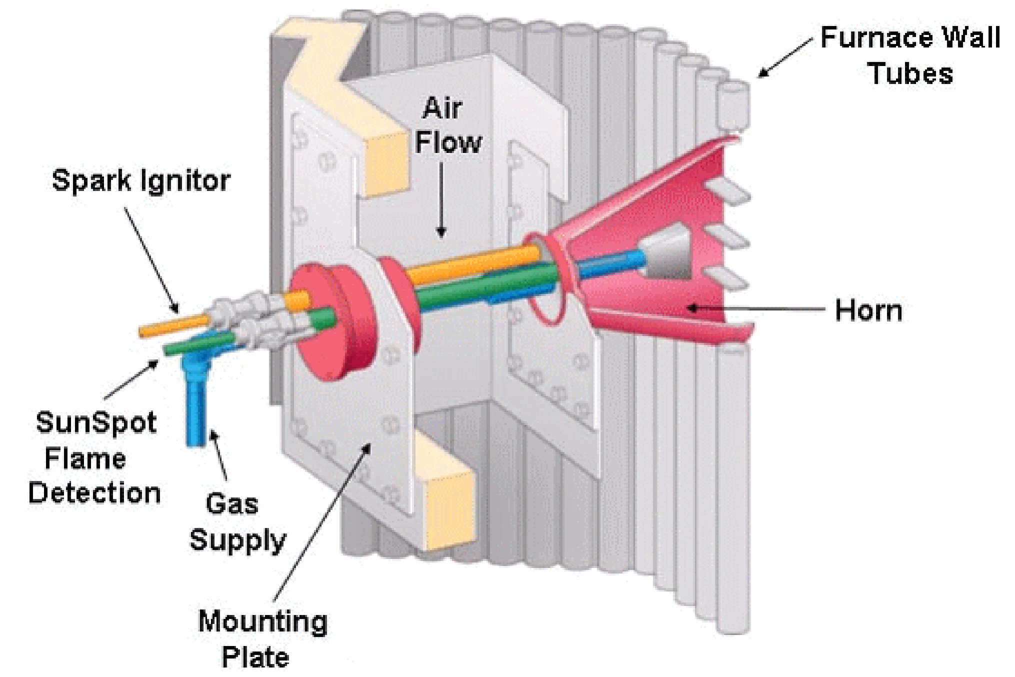
Pressure gauge and test cock

Honeywell Modutrol Motor on butterfly valve to control firing rate

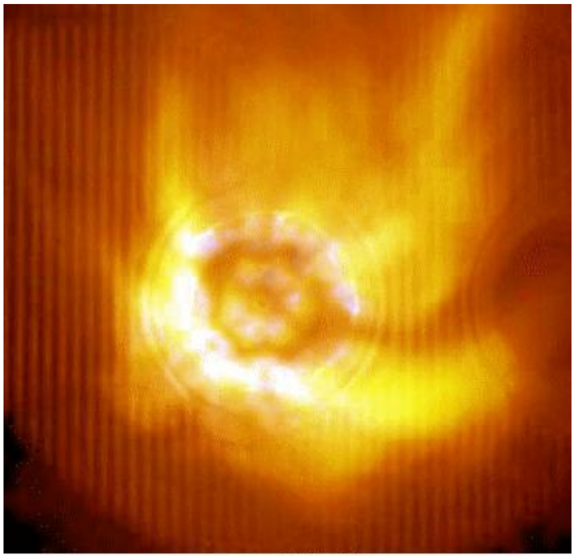
Manual shutoff valve on main gas line



This photo shows most of the components of the gas train piped together



Igniter Flame



Main Flame

Which of these three, oil, coal, or natural gas gives up most of its heat by convection?

Luminosity of the oil flame is high and, as a result, there is considerably more transfer of heat by radiation to the furnace cooling surfaces than from the relatively **non-luminous natural gas flame**.

Blue Combustion Engineering page 10·17

With **gaseous fuels**, the major portion of heat transfer is by convection, and therefore a minimum of surface is installed in the furnace, since practically all the work is done by the gas after it leaves the furnace.

Blue Combustion Engineering page 11·5

A boiler receives little heat by radiation from the gases of combustion. It may receive some heat radiation from the long tongues of luminous flame which result from burning highly volatile bituminous coals. But most of the heat delivered to a boiler by radiation comes from the glowing and incandescent fuel on the grate, and from the highly heated fire-brick lining of the furnace.

Croft's Practical Heat page 126

What is a good CO_2 reading for natural gas?

10% CO_2 is a good reading for natural gas.

Detroit Edison Steam Course Fuels & Combustion page 32

Why is the average CO_2 reading lower for natural gas than for fuel oil?

The higher the percentage of hydrogen in the fuel the lower the percentage of CO_2 in the flue gas. The maximum CO_2 of flue gas for various fuels is: Coal - approximately 19%, Oil - approximately 15.5%, Natural gas - approximately 12%. These figures are for combustion with no excess air. Natural gas has more hydrogen content than fuel oil, therefore the CO_2 reading is lower.

I.U.O.E., Fuels, Oils, Lubricants, page 6-1-48

Why is it good to have a supply of natural gas in a pulverized coal installation?

For ignition and warm up purposes. Also, it is always advisable to have an alternate fuel supply.

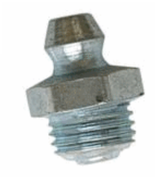
How much excess air should be used with gas fired boilers?

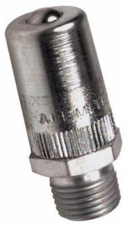
5-10%

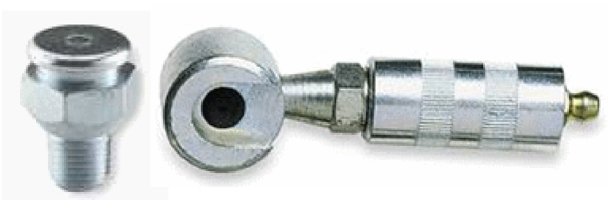
Detroit Edison Steam Course Fuels & Combustion page 21

A gas cock is leaking around the stem. How do you stop the leak?

On a large gas valve you would pump it with a grease gun. There is a fitting on the valve for this purpose, sometimes called a Zerk fitting, Alemite fitting, or Button Head.


Zerk


Alemite


Button Head grease fitting and adapter

Gas Cock Grease

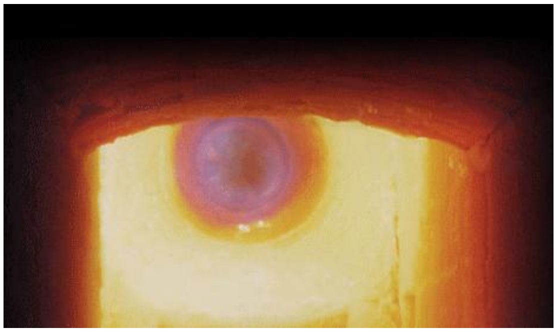
Grease Gun

Describe 4 different types of burners for natural gas?

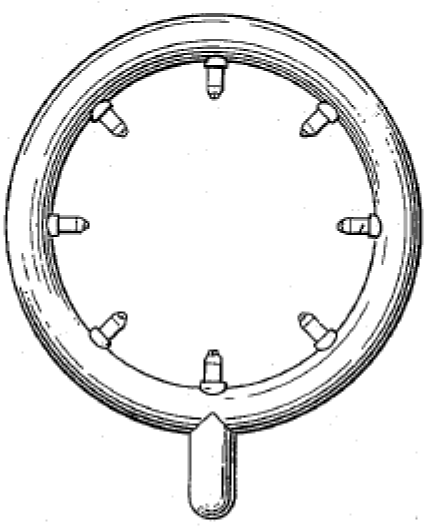
High pressure burners are generally classed as four main types, each indicative of the manner in which the gas is discharged into, and mixed with, the air for combustion. They are; Peabody gas-ring type, the center-diffusion type, the turbine type, and the tangential type.

Blue Combustion Engineering page 11·8

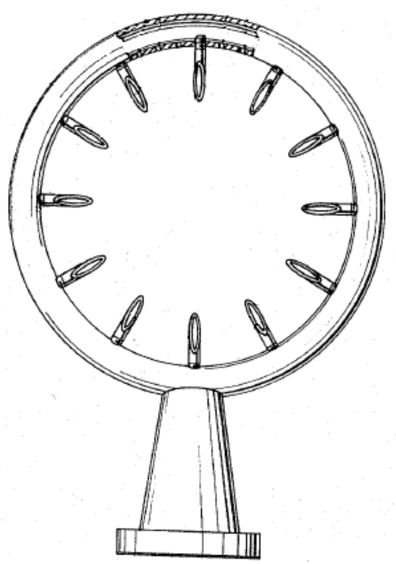
Gaseous fuel burners are perhaps the simplest of all fuel burners. The fuel is already in a gaseous state and it is only necessary to combine and mix the fuel and air in correct proportions and ignite it. Gaseous fuels can be burned with the lowest amount of excess air, compared to other fuels, and contain little or no solid residue. The type of flame produced is determined by the manner and ratio in which the fuels are mixed. Rapid and thorough mixing, obtained by admitting either the air or gas under high pressure, produces turbulence. This results in a short non-luminous flame at a high temperature. There are four main types of burners used in power boiler installations, and they differ from one another only in the manner in which the gas is discharged into, mixed, with the combustion air. All are classified as high pressure burners and use gas at 20 to 30 psi.


Gas Burner Flame

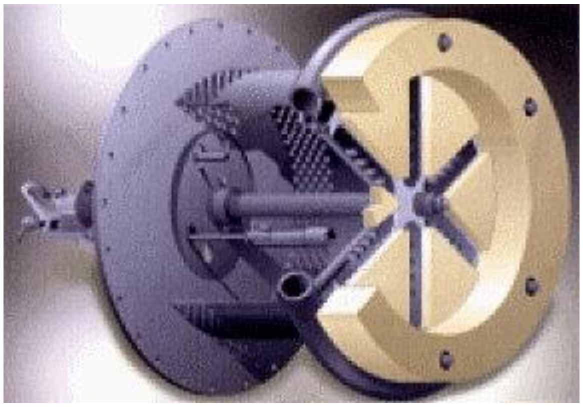
Gas Ring type: this is a high pressure burner which operates on gas pressures of 2 to 25 psi. It is provided with an adjustable air register to regulate the quantity and control the velocity of the combustion air being admitted to the burner. The shape, position and location of the air damper vanes control the rotation of the air flowing through the burner opening to the furnace. The gas-ring is located between the air supply and furnace wall. It is in the form of an annular manifold and surrounds the burner opening. There is a series of orifices drilled around the inner surface of the ring. These distribute the gas angularly in the form of a screen across the air steam toward the center of the burner. Mixing of the gas and air takes place as the air stream flows through this curtain of gas. The gas-air mixture enters the furnace through the curved burner throat, is ignited, and burns with a short transparent flame.



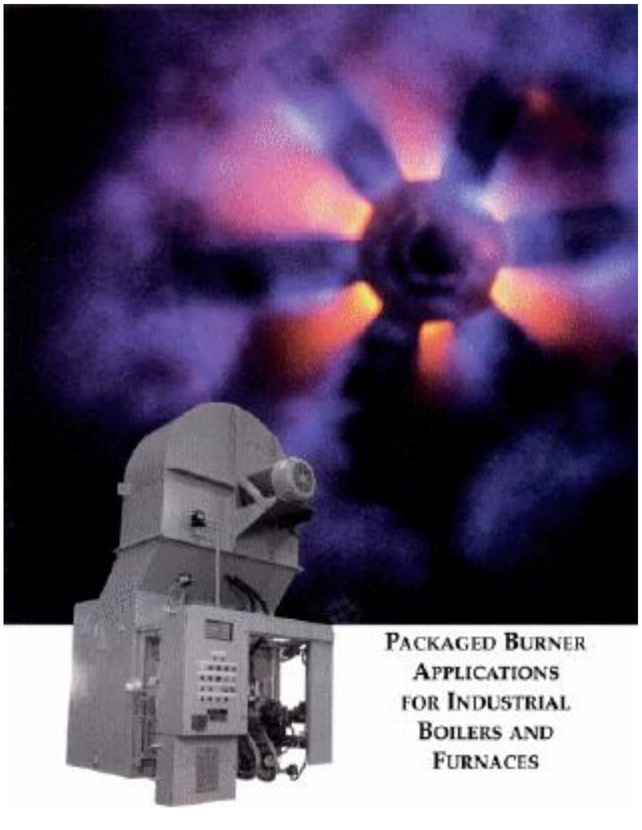
One style of gas ring burner



Another style of gas ring burner

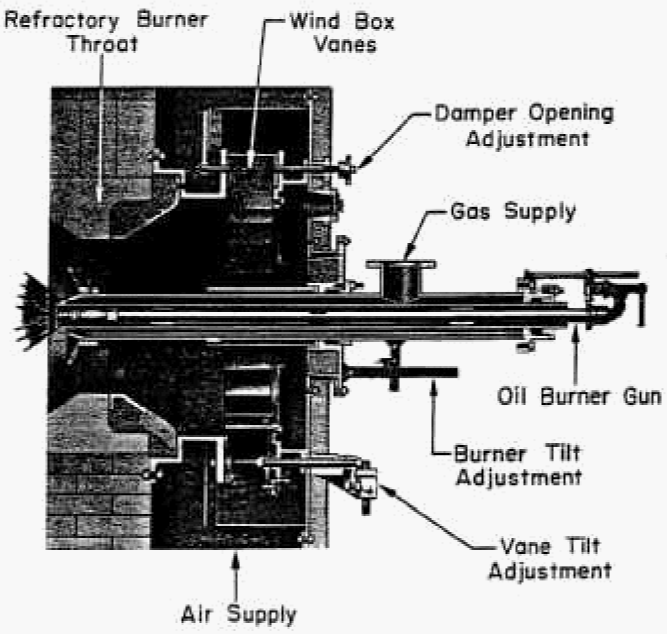


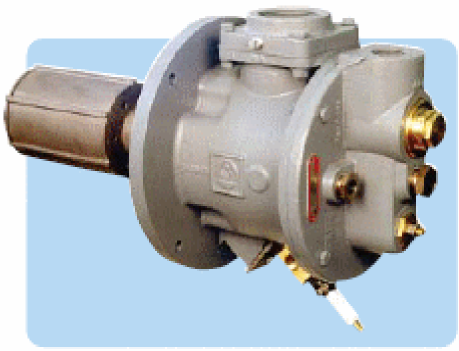
Coen Gas Ring Burner



Center Diffusion type: This is the type of burner in which the gas head with its orifices is located at the center of the burner and remains in this operating position at all times. Gas is admitted to the gas tube under pressure and issues from the tube orifices in the shape of a hollow cone at a wide angle to the incoming combustion air. The diffuser plate mounted near the tip of the gas burner, assures steady and prompt ignition as well as intense mixing of the fuel and air. This mixing permits complete combustion with a minimum of excess air. The vanes in the wind box of the burner are adjustable for both tilt and opening. As the quantity of gas in increased, the vane opening must also be increased to provide the additional combustion air necessary for complete combustion. If additional turbulence is desired, the angle of the vanes may be altered to increase the whirling motion of the combustion air. The flame from this type of burner is short, intense and nearly transparent.

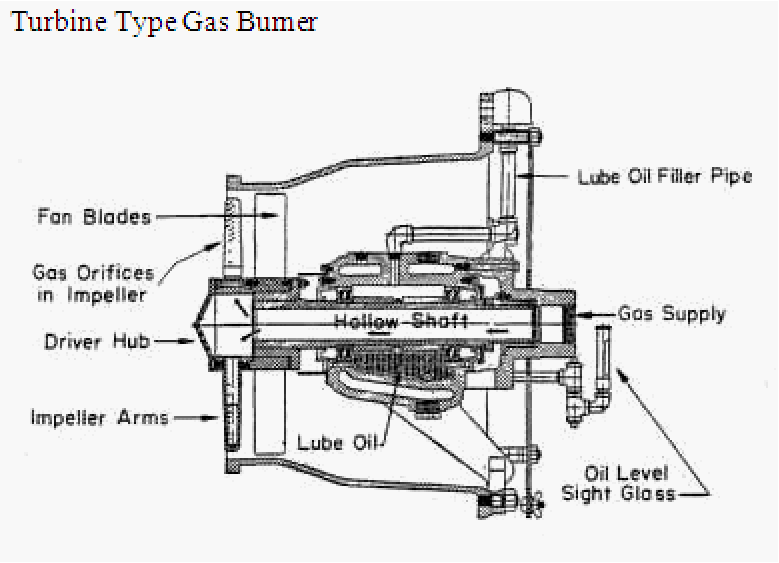
Center Diffusion Type Burner

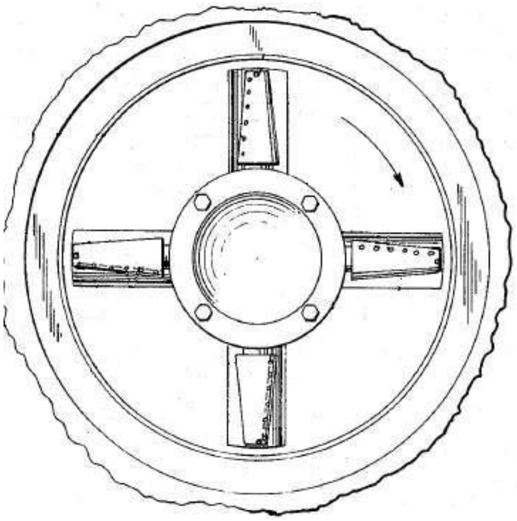




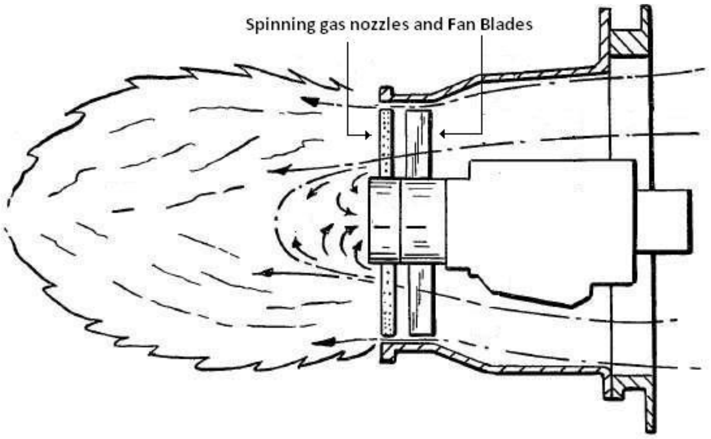
Center Diffusion Burner by North American

Turbine type: The turbine derives its name from its method of operation. Burners of this type use revolving orifices rather than fixed orifices, and these distribute the gas transversely to the air stream while rotating at high speed. In this design, the energy contained in the gas under pressure is used to perform the mixing of the gas with the air for combustion. The burner consists of a casing, in which is mounted, a bearing supported hollow shaft. At the furnace end of the shaft is the drive hub and the hollow arms which form the impeller. These arms are connected to the hollow shaft in such a manner that the gas which is admitted to the hollow shaft flows out into the arms. A large number of small orifices are drilled in the face of each arm. The reaction of the gas flowing out of these orifices causes the fan arms, driver hub and hollow shaft to rotate at high speed. In this case, an integral air fan is fastened to the hollow shaft between the bearing and the driver hub. The pitch of the blades of this fan is somewhat different from the pitch of the gas arms. The fan supplies the necessary air for combustion, and the pitch of the blades causes the air to flow at right angles to the gas streams. This causes an intimate mixing of the gas and air to take place immediately in front of the burner, making it possible to obtain complete combustion with a minimum of excess air. Burners of this type, when properly installed and maintained have no visible flame and provide an almost constant distribution throughout the furnace. Installation cost is relatively low because burners of this type require no duct work or forced air fans.





Front View



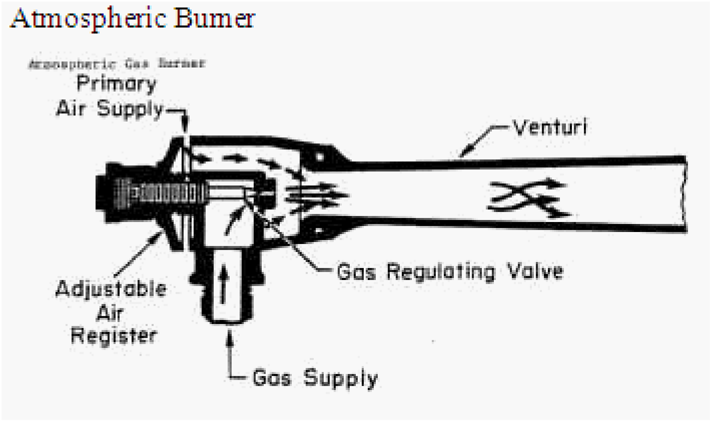
Side View

The atmospheric gas burner is the fourth type of burner. An atmospheric burner simply permits the air required for combustion to enter the combustion chamber, or it draws air into the combustion chamber from the area surrounding the burner. Two methods are used to draw air into the combustion space - natural draft or inspiration. A typical atmospheric burner combines both methods.

Detroit Edison Steam Course Fuels & Combustion
Honeywell Flame Safeguard Controls pg. 6

Gas burners should never be lit until: The furnace has been purged at least 5 minute with an airflow equal to at least 50% of full load. Open the uptake damper to ventilate the furnace and boiler setting thoroughly. If forced and induced draft fans are provided, operate them for at least five minutes before lighting off. This is of particular importance where gas, oil, or pulverized fuel is used, either as the principal or the auxiliary fuel.

Blue Combustion Engineering page 30·25



What is the best type of flame when burning gas?

A short non-luminous flame. A gas ring, in the form of an annular manifold, located between the air register and the furnace wall, surrounds the burner opening. A series of orifices, drilled around the inner surface of this ring, spray gas angularly, in the form of a screen, across the air stream toward the center of the burner opening. The resultant uniform gas-air mixture enters the furnace through a curved throat opening, where it burns with a short, transparent flame.

Blue Combustion Engineering page 11·8

Other Gases

Can coke oven gas be used as a fuel directly from the coke oven?

Yes it can.

Coke oven gas results from a true distillation process used for the manufacture of coke from raw coal in the modern byproduct coke oven. Substantially all volatile matter in the raw coal is distilled off, and the vapors thus obtained contain fixed gases, liquids and solids. Various methods of cooling, separation, and extraction are used to recover the liquids and solids. Some of the fixed gases are then used to heat the coke ovens, while the remainder is available for boiler, process, or domestic fuel. Combustion characteristics of coke oven gas are similar in many respects to those of natural gas, and therefore the same furnace design factors - with respect to heat-liberation rate, extent and arrangement of cooling surface, placement of burners, and length of flame travel apply equally well.

Blue Combustion Engineering page 11·29 and 30·26

What is the heating value of coal gas or coke oven gas?

The higher heating value is approximately l/2 that of natural gas.

It ranges from 460 to 650 BTU per cubic foot.

Blue Combustion Engineering page 11·29

What is the reason for the wide variation of heating values of the various gasses?

The percentage of hydrocarbons present

Steam its Generation and Use by Babcock and Wilcox 40th edition page 8-11

What is blast furnace gas made up of?

It is a good fuel when cleaned, and since it contains a high amount of nitrogen, the first equation would be more correct, if the fuel is cleaned.

The average composition of blast furnace gas is 58% N_2, 27% CO, 12% CO_2, 2% H_2, and some CH_4. Blast furnace gas is a by-product of iron making, usually burned on-site, and has a high heat value of 90-100 BTU/cu ft.

Detroit Edison Steam Course Fuels & Combustion page 13

In most cases, gaseous fuels are measured and purchased in terms of cubic feet. In some cases however, they are purchased by heating value expressed as therms. What is a therm?

One therm is equal to 100,000 BTU. At approximately 20,000 btu/lb., one therm is equal to 100 cu. ft. of natural gas

Detroit Edison Steam Course Fuels & Combustion page

Why do gaseous fuels vary in BTU per cubic foot?

Natural gases are sometimes divided into three classifications: high inert type, high methane type, and high BTU type.

These classifications are defined in table 6-1-8

The composition of a particular natural gas relates to its geographical origin. As a result, the composition of the available in a given location may vary slightly from time to time as gas is drawn from various sources. Nonetheless, composition usually is controlled to maintain a fairly constant heating value for control and safety purposes. The heating values of natural gases vary from 900 to 1200 BTU per cu ft. The usual range is from 1000 to 1050 BTU per cu ft.

Table 6-1-8

Group	nitrogen%	specific gravity	methane%	BTU/cu ft, dry
high inert	6.3-16.20	0.660-.708	71.9-83.2	958-1051
High methane	0.1-2.39	0.59-.614	87.6-95.7	1008-1071
High BTU	1.2-7.5	0.62-.719	85-90.1	1071-1124

IUOE fuels furnace burners page 6-1-15

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